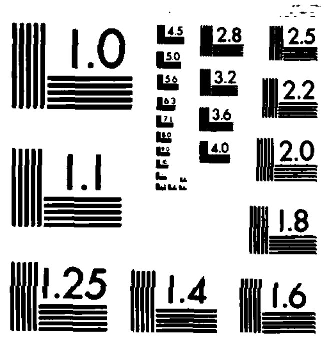
AD-A155 643 MINICOMPUTERS AND NAVAL MOBILE CONSTRUCTION BATTALION PRODUCTIVITY(U) NAVAL POSTGRADUATE SCHOOL MONTEREY CA G R WEGENER DEC 84 1/2

UNCLASSIFIED F/G 9/2 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

MINICOMPUTERS

AND

NAVAL MOBILE CONSTRUCTION BATTALION

PRODUCTIVITY

by

Gary R. Wegener

December 1984

Co-Advisors: D. Boger, K. Euske

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO. A155 643	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Minicomputers and Naval Mobile Construction Battalion Productivity		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis; December 1984
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Gary R. Wegener		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93943		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93943		12. REPORT DATE December 1984
		13. NUMBER OF PAGES 102
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report)
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

DTIC COPY INSPECTED 1

Accession For
NTIS GRA&I
DTIC TAB
Unannounced
Justification
By
Distribution/
Availability Codes
Dist | Avail and/or Special
A/1

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Minicomputer
Productivity
Naval Mobile Construction Battalion

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

In 1978-79, minicomputers were installed at the five U. S. Naval Mobile Construction Battalion mainbody deployment sites, based upon a study that projected increased productivity. This thesis examines the issue of productivity in construction battalions. It developes and tests a productivity index, and examines and tests a level of effort indicator for changes coincident with the introduction of the minicomputers.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

S/N 0102-LF-014-6601

unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

The productivity index shows no significant differences before and after the introduction of the minicomputers. This is judged to be inconclusive however, because of the assumptions necessary in development of the index. The level of effort indicator does show a statistically significant difference.

The lack of a commonly accepted productivity index for use within the Naval Construction Force is viewed with concern; recommendations are made for the development of an objective index against which performance may be measured.

Approved for public release; distribution is unlimited.

Minicomputers and Naval Mobile Construction Battalion Productivity

by

Gary R. Wegener
Lieutenant Commander, Civil Engineer Corps, United States Navy
B. S., University of California, Berkeley, 1971

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN MANAGEMENT

from the

NAVAL POSTGRADUATE SCHOOL
December 1984

Author: Gary R. Wegener

Approved by: D. C. Boger, Thesis Advisor

K. Euske, Co-Advisor

Willis R. Greer, Jr., Chairman,
Department of Administrative Science

Kneale T. Marshall,
Dean of Information and Policy Sciences

ABSTRACT

In 1978-1979, minicomputers were installed at the five U. S. Naval Mobile Construction Battalion mainbody deployment sites, based upon a study that projected increased productivity. This thesis examines the issue of productivity in construction battalions. It develops and tests a productivity index, and examines and tests a level of effort indicator for changes coincident with the introduction of the minicomputers.

The productivity index shows no significant differences before and after the introduction of the minicomputers. This is judged to be inconclusive however, because of the assumptions necessary in development of the index. The level of effort indicator does show a statistically significant difference.

The lack of a commonly accepted productivity index for use within the Naval Construction Force is viewed with concern; recommendations are made for the development of an objective index against which performance may be measured.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. INTRODUCTION

United States Naval Mobile Construction Battalions (NMCBs) are units of the Naval operating forces, responsible for providing responsive military construction support to naval, Marine Corps and other forces in military operations. This has generally taken the form of advance base facilities in direct support of combat personnel.

In 1978-79, minicomputers were installed at each NMCB mainbody site, both deployed and homeport, based on an Automated Data System Development Plan which showed a benefit to cost ratio of twenty-three. Software packages included construction project management, construction equipment management, word processing, and personnel roster maintenance.

The costs have remained close to original estimates through 1982, according to Mr. Berninger of the Civil Engineering Support Office (CESO) in Port Hueneme, California, however the benefits derived from introduction of the minicomputers have been difficult to quantify, leading to doubts as to the viability of the program.

SCOPE OF THESIS

This thesis examines available data to determine what productivity related changes, if any, have occurred as a result of the introduction of minicomputers in the NMCBs. The analysis is based primarily on past deployment data contained in deployment completion reports covering a 5 year period from 1977 through 1981, and on project data for 151 projects at three mainbody deployment sites (Camp Cummins, Diego Garcia; Silver City, Rota, Spain; and Camp Moscript, Puerto Rico).

B. PROBLEM STATEMENT

The question of interest in this study is whether NMCBs should maintain or expand their organic computer capability, or return to manual, construction management methods.

The addition of a minicomputer capability to the NMCB mainbody sites was projected to increase productivity at each site, resulting in an average 15 percent decrease in construction durations [Ref. 1]. There is concern in the Naval Construction Force (NCF) regarding the wisdom of the original decision. This concern is influenced partly by the difficulty in quantifying the benefits, if any, that have resulted from the computer's introduction, and in particular, how those benefits relate to overall productivity.

A study by Arthur Anderson and Company, the accounting and consulting firm, has projected that "the construction industry is likely to be at the leading edge of growth in the personal computer industry." Reasons cited include the "dynamic nature of the construction industry", the computers' ability to "provide more complete and accurate control over the progress of a job", and the contention that "it also serves as a motivation for engineers and project managers schooled in computer techniques." The study also projected that "new software products to serve the construction industry will continue to appear in a wild profusion." [Ref. 2]

C. OBJECTIVE OF THE RESEARCH

It is the intent of this research to examine existing project and battalion deployment data and ascertain whether any statistically significant changes which can be related to productivity occurred coincident with introduction of the computers.

D. HYPOTHESES

Two productivity indices are developed, one dealing with the dollar value of construction completed per manday of direct labor, and another dealing with the percentage of direct labor obtained from a relatively fixed labor force, the NMCB. The hypotheses listed below are used to test if these productivity indices have changed with the introduction of the computers.

The dollar cost of material in place per direct labor manday is statistically different for construction projects accomplished since the introduction of minicomputers at the mainbody sites than for those accomplished before their introduction.

Figure 1.1 Hypothesis I.

The percent direct labor experienced by NMCBs since the introduction of minicomputers at mainbody deployment sites is statistically different than that experienced prior to their introduction.

Figure 1.2 Hypothesis II.

E. ACKNOWLEDGEMENT OF THE STUDY'S LIMITATIONS

Given that the minicomputers were introduced in the battalions in 1978-79, prior to the conception of this analysis, precludes the application of controlled experimental techniques in measuring the effects of minicomputers on

construction productivity. This imposes the critical restriction that analysis must rely on data then available, which was not specifically designed for this study.

The lack of controlled experimental techniques is recognized as having serious impact on the validity of any findings of this research. Nonetheless, it is felt that an analysis of available data is an important prerequisite to any decision process regarding the future of minicomputers in the NCF. Accordingly, this research examines available data, constructing the best productivity measures obtainable from that data, and ascertains whether any productivity changes are discernable, while recognizing fully the limitations of those findings.

F. ORGANIZATION OF THESIS

Chapter One identifies the basic problem area being studied, states the objectives of the research and the related hypotheses in general terms, and addresses the limitations and organization of the study.

Chapter Two provides background information on the mission, organization, and tasking of NMCBs, and the context within which this study is being made. It addresses the concept of productivity, its seemingly elusive nature, and the practical difficulties associated with its measurement, particularly in the construction industry. The chapter concludes with an examination of productivity questions within the NMCBs.

Chapter Three begins with a definition of a cost per manday term as a new productivity index, based upon data available within the Naval Construction Force (NCF). Factors are developed as independent variables for subsequent analysis. An initial refinement of data is then followed by a discussion and statement of the hypotheses,

the final analysis, and findings. The chapter concludes with a section on sensitivity analysis.

Chapter Four is structured similarly to chapter three. Percent direct labor, a level of effort indicator, is discussed as an established productivity measure in the NCF. The development of data elements is then presented for 40 of 42 deployments, covering a five year period at five deployment sites. A discussion of the hypotheses follows, with the chapter concluding with the analysis, findings, and sensitivity analysis.

Chapter Five, Conclusions and Recommendations, summarizes the analysis and provides conclusions and recommendations for further study.

II. PRODUCTIVITY MEASUREMENT WITHIN THE NMCBS

The first section of this chapter describes the NMCBs, including their organization, mission, concept of operations, and typical peacetime tasking. This section is intended to provide an understanding of the basic environment within which productivity concerns are addressed.

The second section reviews the concept of productivity, addresses the background leading to the current level of appreciation of the importance of productivity, and reviews the definition of productivity and the practical difficulties in its measurement. General construction industry productivity is discussed. This section is intended to provide information on both the progress made in the field of productivity analysis and the uncertainty that remains.

The chapter concludes by addressing questions of productivity in the private and the public sectors, and specifically the NMCBs. While there are some corollaries between civilian construction firms and NMCBs during peacetime, there are also many dissimilarities.

A. U. S. NAVAL MOBILE CONSTRUCTION BATTALIONS (NMCBS)

1. Mission and Composition of the NMCBs

The mission of the NMCBs is delineated in a Chief of Naval Operations Instruction as follows:

> The active NMCBs are established units of the Naval operating forces and are components of the Naval Construction Forces (NCF). The mission of the NMCBs is to provide responsive military construction support to naval, Marine Corps and other forces in military operations, to construct base facilities, and to conduct defensive operations as required by the circumstances of the deployment situation. In time of emergency or disaster, NMCBs shall conduct disaster control and recovery operations, including emergency public works operating functions, as directed. [Ref. 3]

An NMCB has a normal peacetime allowance of 21 officers and 562 enlisted men, 464 of whom are of construction ratings, i.e. Occupational Field 13 [Ref. 4]. A summary of the peacetime manning allowance is provided as Figure C.1 in Appendix C. The battalions have a specific, detailed allowance of supplies, construction material, tools, equipment and vehicles. This is referred to as the Table Of Allowance, or TOA. An indication of the intent of the allowance is provided by the following quote:

> The organic NMCB Table of Allowance will be capable of sustaining for 90 days (1800 construction hours), without resupply, construction operations planned or envisioned under contingency or general war conditions... The allowance may be utilized for peacetime employment of the NMCBs for training and maintaining readiness, and may be augmented with additional assets assigned to the Commanders in Chief, U. S. Pacific and Atlantic Fleets, as necessary, to meet specific employment requirements... Construction materials, special tools and special equipment not in the NCF inventory but required for direct use in accomplishing the project, or funds for the the procurement thereof, are the responsibility of the project sponsor... [Ref. 3]

The concepts of operation for NMCBs during wartime and during peacetime are provided as follows:

> NMCBs are intended to provide responsive construction support at Navy support bases in forward areas or in combat zones to which Navy and/or Marine Corps forces are committed. NMCBs shall be capable of constructing advanced base facilities that may be reasonably expected to be required in the combat zone or at forward area support bases. Normally, in the combat zone, NMCB-built facilities will be limited to initial, intermediate and temporary construction standards ...; capability for permanent construction at Navy support bases, however, will be maintained. NMCBs will not normally be tasked to perform maintenance on shore facilities. Peacetime employment. In peacetime, NMCBs shall undertake construction projects which maintain their construction capabilities and enhance their readiness to accomplish this mission. Special emphasis will be placed upon projects which contribute directly to overall improved Navy readiness. [Ref. 3]

2. Deployment Sites

During the period 1977-81, the eight active NMCBs were homeported at the Construction Battalion Centers (CBC) at Gulfport, Mississippi and Port Hueneme, California. They deployed to Diego Garcia, British Indian Ocean Territories; to Okinawa, Japan; to Guam; to Puerto Rico; and to Rota, Spain. Each battalion additionally deployed detachments from the mainbody to various military bases in the general geographic area of the mainbody deployment site, as required by their tasking. The deployment cycle was normally 6 months in homeport, followed by 8 months deployed, with the battalion rotating through four of the deployment sites on consecutive deployments. NMCB Three was the exception. Beginning in April, 1977 it was split into a Blue and a Gold team and the teams were deployed to Okinawa on a 7 month rotational basis. This continued through mid-1982.

3. Construction Tasking

While construction tasking varied from deployment to deployment, NMCB Four's deployment to Rota, Spain in 1980 is an example of a battalion's tasking. It had 25 principal construction projects and 10 fill-in projects (defined as under 100 mandays of direct labor) at the mainbody site, representing 14,000+ mandays of labor. At the six different detachment sites, there were 27 different principal projects, representing over 23,000 mandays of effort. Projects ranged in scope from a 22,500 square foot commissary store (25,000+ mandays spread out over five deployments) to simple projects of under 100 mandays that are completed in a month.

The most intense tasking was the construction of the Naval Support Facility at Diego Garcia in the Indian Ocean. That eleven year effort included pier and airfield

facilities, water desalizination, ship and aircraft fuel storage, power facilities, and all personnel support and related public works support facilities.

Since a price tag is not set on SeaBee construction, it is not possible to determine exactly how the Naval Construction Force compares with the major United States construction contractors, based on volume of business. Using typical figures for battalion size (562 enlisted), deployment direct labor rate (34 percent), 22 days of construction a month (5 1/2 days a week), 9 hour days, and the April, 1976 average wage and fringe benefit pay scale for skilled building trades ($11.52/hour) [Ref. 5], the eight battalions collectively would put in close to a quarter million mandays, or $26,150,750 of direct labor effort a year, over the 5 deployment sites. This figure is exclusive of indirect, overhead, and material costs. While these costs will vary by type and location of the project, it is the experience of the author that a conservative estimate for indirect and overhead costs would be 30 percent and 15 percent respectively, of the direct labor and material costs. Assuming for comparison that $29.29 of direct material costs are associated with each manday of direct labor (see table 884cpm) and using figures of 30 percent indirect costs, 15 percent overhead costs, and 10 percent profit, the annual value of work in place would equal $55,153,960 as shown in Figure 2.1 below. At $50 million, the Naval Construction Force would have ranked around 182 among the Engineering News Record's top 400 United States contractors in 1975 [Ref. 6: p. 74]. A key management concern for a force of this size is how to improve productivity.

Direct Labor Mdays	562 x .34 x 22 x 12 x 5 =	252,225
Direct Labor Cost	252,225 x 9 x$11.52 =	$26,150,750
Material Costs	252,225 x $29.29 =	7,387,688
Total Direct Costs		33,538,438
Indirect Costs	Direct costs x .30 =	10,061,531
subtotal		43,599,969
Overhead Costs	Direct & Indirect x .15 =	6,539,995
subtotal		50,139,964
Profit	plus 10 percent	5,013,996
Total		$55,153,960

Figure 2.1 Estimated Annual Work in Place by the NCF.

B. PRODUCTIVITY

1. General

Productivity is a pervasive factor in life, whether or not it is recognized as such.

> One key economic factor adversely affecting the United States is the dramatic general decline in the rate of increase in productivity. This affects the U. S. trade balance, the acceleration of inflation, the number of jobs available, and the very quality of life. The 1978 Economic Report of the President of the United States cited it as 'one of the most significant problems of recent years.' [Ref. 7: p. 137]

a. Productivity, Efficiency, and Effectiveness

For any construction organization, productivity statistics can be aggregated at various levels and used differently, depending upon the level of aggregation. The basic level of productivity analysis is the unit production of specific work items per man-hour of labor input. While this can generally be objectively determined, it is difficult to use in a practical sense. The unit production concept results in a bewildering sprawl of data. Individual operations can only be compared with similar operations in

the same generic family. Comparisons are not possible between dissimilar work of the same trade or operations of different trades.

A more advanced level would be that of the finished product, be it a new building, a car, or any other product that has value in and of itself and which is related to the inputs required to produce it. These two levels of productivity analysis can be related to efficiency and effectiveness. Efficiency is seen as productivity at the unit production level, or micro-productivity. Efficiency is relatively easy to determine and highly reliable, yet it is of limited usefulness due to its severely restricted applicability. Effectiveness on the other hand can be related to productivity at the project level, or macro-productivity. This attempts to measure how effectively all the input resources were utilized in arriving at the finished product. Macro-productivity is relatively difficult to determine, and consequently it is often of questionable reliability. Properly developed however, it could be extremely useful in comparing different management techniques, capital/labor mixes, and construction techniques. This information is summarized in figure 2.2.

The Hierarchy Model of Construction Productivity [Ref. 7] goes further and suggests that productivity is influenced at all levels of our society, from the formulation of national policy on such diverse issues as the federal budget, the environment, and social programs (i.e., support for small business and handicapped programs) to the development of building codes, union/management relations, and the forms of contractual documents utilized in the industry.

In short, while it is often easiest to focus on the productivity of the individual worker, construction efficiency or macro-productivity is most effected by decisions made before construction begins.

	Reliability	Ease of Development	Usefulness
Micro-Productivity Efficiency "Unit" index	high	easy	low
******************	continuum	************************	
Macro-Productivity Effectiveness "Project" index	low	difficult	high

Figure 2.2 Productivity, Efficiency, Effectiveness.

> Effectiveness, not efficiency, is the major issue. Increased productivity is obtained by working smarter, not necessarily harder. People generally want to produce and feel productive. They will attempt to appear productive and "do work" even if it isn't "effective work." The problem is to establish a climate for the most effective operation considering all elements of the work process. [Ref. 7: p. 142]

b. The Productivity Ratio

The common measure of productivity is the ratio of physical output, such as products or services, to the inputs, labor, capital and natural resources, required to produce that output. The inputs listed are commonly referred to as the factors of production. When all three of the factors of production are used, the resultant productivity ratio is often referred to as the total factor productivity ratio, or more accurately a multi-factor productivity ratio in recognition that some inputs in labor, capital, or natural resources will not be measurable. Often productivity data refers to only one of the factors of production, the most common being labor. Such a productivity ratio would properly be refered to as a labor productivity ratio. [Ref. 8: p. 3] [Ref. 9: p. 25]

The usefulness of a particular productivity ratio lies in its comparability with similar ratios. Taken alone, it provides little if any value. Productivity is good or bad only when compared to another period's productivity, or another unit's productivity if the productivity ratios are derived in the same manner. Time series productivity statistics are published by various sources such as the Department of Commerce, the Department of Labor's Bureau of Labor Statistics, or various private productivity research centers such as the American Productivity Center.

The term productivity ratio, while commonly used by many people, is often misunderstood. It is in a sense, an abstract entity. Basically this is because the inputs and outputs are nominal units of resources and associated products, respectively, with measurements often made in dollar terms out of practical necessity. The dollar measures are adjusted for inflation, changes in quality, and price fluctuations due to varying market conditions. With a 5 percent change in productivity being a typical range of interest in productivity studies, it is easy to appreciate the difficulties encountered in data refinement. While it is highly doubtful that a productivity ratio could be used meaningfully to determine average profit margins, a total output to total input ratio would suggest this possibility.

The value of productivity statistics lies in their ability to communicate trends in productive efficiency and the relative contributions to productivity of each of the factors of production. If intra-industry comparisons were available and valid, these figures would give a macro-indication of the inherent productive capability of each firm. Whether that relative capability is achieved is a result of a number of influences, not the least of which are general economic conditions.

2. The Development of Productivity Measurement

Productivity concepts have evolved from a recognition of labor as the sole productive input to the recognition of capital goods and land as part of the total factor productivity concept which is in wide use today. In 1776, Adam Smith wrote

> The annual produce of any nation can be increased in its value by no means other than by increasing either the number of its productive labourers, or the productive powers of those labourers who had before been employed. [Ref. 10: p. 20]

The additional recognition of man-made capital goods and land as inputs in the production function, in the latter nineteenth century, provided the basis for our present day concept of total factor productivity. Some refinements have addressed human resource accounting concepts in adjusting the quality of labor input and environmental/quality of life considerations as part of the output.

Interest in productivity in the United States has usually been inversely related to general economic conditions. The first estimates in the United States were by the Bureau of Labor of the Department of Interior in the mid-1880's, resulting from concern about the causes and consequences of industrial depression. The National Bureau of Economic Research, a private, nonprofit organization, began developing and publishing productivity studies of various industries and the national economy in the 1930's spurred on by the Great Depression.

The National Research Project of the Works Progress Administration provided another intensive set of studies in the 1930's. Upon termination of this Project, productivity measurement responsibilities were transferred to the Division of Productivity and Technological Development in

the Bureau of Labor Statistics (BLS) in 1940. The BLS continues to collect and publish productivity statistics, having progressed from output per hour in selected industries to plant level productivity studies and annual and quarterly estimates for the entire economy, which can be subdivided into major segments of the economy. Valid international comparisons of productivity of a limited number of countries began in the 1950s. [Ref. 11]

While the Labor Department's productivity figures have always been based on labor productivity, the Commerce Department has published total factor productivity estimates for the nonfinancial corporate sector on an irregular basis since 1972. The Department of Agriculture and Department of Interior publish productivity ratios for segments of the economy within their fields of interest.

Private sector research and statistics on productivity are provided by the National Bureau of Economic Research, the Conference Board, the Business Roundtable, and by various institutes and universities. In addition, productivity centers have gained prominence both in the U. S and overseas, generally as government sponsored organizations responsible for three major functions:

1. Education: to sponsor studies, to provide information and to promote public understanding of the significance of productivity increases.
2. Promotion: advocacy within the government of policies and programs to promote productivity.
3. Coordination: providing a forum in which representatives of labor, management, government, and other groups can exchange views on productivity. [Ref. 10: p. 24]

a. Measurement Difficulties

Productivity is easy to understand but difficult to operationalize. There are difficulties in identifying and quantifying the inputs in the denominator and the outputs in the numerator of the productivity ratio. Research on productivity is normally constrained by the availability of applicable data. The relevance of a particular theory on productivity change lies in its ability to explain the past and project into the future. Studies on time series changes in productivity often must rely on data that has been collected for other purposes. This is a difficult process, at best. Labor productivity studies tend to be more common as labor data is routinely collected and retained for other purposes. [Ref. 12] [Ref. 9]

If spurious fluctuations in the productivity ratio are to be eliminated, the denominator must include all inputs, and only those inputs, which result in the outputs included in the numerator. If additional inputs are inadvertently included, changes in those extraneous inputs, while having nothing to do with the actual output being considered, would result in changes in the related productivity ratio.

Likewise, the outputs must include all and only those outputs which result from the inputs in the denominator. If additional outputs are included in the numerator which are unrelated to the input in the denominator, measured changes in those outputs would occur when there was no change in the input, resulting in an erroneous productivity ratio. Similarly, if some inputs are omitted, changes in them, which would affect output, would not be included in the denominator, thus distorting the productivity ratio. [Ref. 9: p. 24]

Reflection on the significance of the cause and effect requirement when determining productivity ratios illustrates the difficulty in establishing accurate measures. Consider the following:

Activity: Trench Excavation

Output: Ditch, point A to point B.
Input: One laborer and one shovel.

$$\text{Productivity ratio} = \frac{\text{(Ditch, point A to B)}}{\text{(laborer and shovel)}}$$

Assuming that it took the laborer one day (eight hours) to dig the twenty feet of ditch, using one shovel, then the productivity ratio is 20/8 =2.25 linear feet of ditch per laborer manhour, w/shovel.

Since the value of the productivity ratio lies in its comparison with other comparable ratios, it is reasonable to ask several questions. How much use would one have for such a ratio? Should it be more generalized? Have all the factors that would affect the productivity of the laborer been accounted for? The answers to these questions are all related.

It is highly probable that the laborer's output was affected by several things not addressed, such as the cross-section of the ditch, the terrain that it was located on, the relative ease of digging the material encountered, the type of shovel, the ability and motivation of the laborer, the weather conditions, and whether shoring was required. These considerations must be identified and dealt with in one of two ways: 1) either become part of the description of a much more restricted productivity ratio, or 2) properly quantified as part of output or input. The second option differs from the first in a practical sense,

only if the various input and output factors can be combined in like terms. Units are an obvious problem; the practical solution is to use dollars as a measure of both "nominal units" of output and of input.

Having labor priced at $10.00 an hour, depreciation on the shovel priced at $1.00 per hour, and the finished product priced at $100.00, the productivity ratio thus becomes $100/ $80 + $8 or 1.13. More difficult ditches (i.e., harder material, adverse weather) would "sell" at a higher price. But likewise, they would take longer to dig and/or require an implement other than a shovel, with a different depreciation rate. The productivity of different ditch digging operations could be compared, given that both inputs and outputs could be accurately priced.

Manufacturing, as an industry, lends itself more to productivity analysis. In general, it is a relatively repetitive process under relatively controlled conditions, where profit is strongly related to productivity. Still, measurement difficulties persist. A 1979 National Academy of Sciences report titled Measurement and Interpretation of Productivity noted three general types of quality changes in the output of durable goods, yet indicated only one of the types is properly dealt with in Bureau of Labor and Statistics reports [Ref. 11: p.100-102].

> The limitations of the present methodology are apparent when it is noted that quality change can take one of three forms. First, a quality change can take the form of a change in the quantity of costly resources used to produce a product. This "type 1" quality change, such as the addition of a remote control device to a television set or a heavier bumper to an automobile, is adequately treated now for many categories of goods. Second, a quality change can be achieved by a technological innovation that raises the quality of a product without any increase in current resource inputs. An important example of this "type 2" quality change is the development of new models of electronic computers that have larger memories and more rapid computational abilities but that cost roughly the same as the models they replace. Third, any consumer or producer durable good simultaneously provides services to its users and imposes costs on them in the form of operation expenses,

> particularly energy requirements and maintenance. These operation costs may be trivial for some durable goods (furniture may need only an occasional bit of polish), but for some goods, such as electrical generating equipment and commercial jet aircraft, cumulative operating costs over a product's life may be many times larger than the initial capital cost. This "type 3" quality change refers to any design changes in durable goods that result in higher or lower operating costs, holding constant both the quantity of services provided by the good and the wages and prices of the inputs used in its operation. A reduction in the price of gasoline that makes automobiles less expensive to operate is not a type 3 quality change, but the redesign of an engine to improve fuel efficiency is.

The report goes on to note that the Bureau of Labor and Statistics has well established procedures for dealing with type 1 changes, but is generally ineffective in adjusting the value of output for type 2 and 3 changes, due presumedly to difficulties in objective measurement. One must question the validity of productivity statistics that do not give credit in evaluating output to design innovations that increase the operational capability of a product or that reduce the ownership costs of the product.

The above examples are intended to convey an idea of the extent to which inputs and outputs can be identified, quantified, and adjusted, in developing productivity statistics.

Some economists refer to the change in output that is unexplained by a related change in input as a "measure of our ignorance." Increases in output do not happen by chance; they are caused by something. That something must be identified to determine if in fact it is an input previously overlooked. If so, it should be quantified and included, thus reducing the unexplained change in output. It is generally felt that a more complete understanding of the basic production function will make possible proper quantification of all inputs, many of which are presently unknown or improperly quantified. With such a search proceeding to narrow "the extent of our ignorance" it is

easy to appreciate the range of factors considered by economists in the measurement of inputs and outputs, and the resulting complexity of the process. [Ref. 12: p.1031,1035]

3. Construction Industry Productivity in the Private Sector

The construction industry is a vital segment of the national economy. It employs over 10 percent of the work force, contributes over 10 percent of the GNP, and significantly affects commitments of 30-40 percent of our national resources. "The industry is highly fragmented and diversified and is composed of over 800,000 construction contractors, ranging from a few giants ... to the majority of contractors that employ less than 20 employees." [Ref. 7: p. 138] [Ref. 8]

Because of its size, productivity within the construction industry has important macro-economic implications for the country as a whole. Its diversity however causes *significant problems in productivity* measurement. Recent literature varies on the extent of decline in productivity growth in construction, but there is general agreement that it has declined markedly more than productivity in the economy as a whole. [Ref. 7]

It should be noted that despite the complexities illustrated above, productivity statistics are more readily available for manufacturing than for the construction industry. This is a direct reflection of the construction industries diversity, relative to the quantities of output produced. The Bureau of Labor Statistics data on construction productivity are considered unreliable by the BLS and are not published. Construction Productivity Frontiers [Ref. 13] notes that "construction is among the major industries whose productivity we know least about."

4. Productivity in the Naval Mobile Construction Battalions

In public sector productivity studies, an inherent difficulty is that the product is not normally sold, and as such the standard method of establishing the value of the product is lost. This invariably leads to the use of changes in inputs as proxies for changes in output. [Ref. 9: p. 23]

In the NCF, productivity studies are hampered by the two major factors mentioned above: it involves construction work and it is in the public sector. Measurement difficulties do not negate the need for analysis however, they only complicate it.

As with any military unit, the NMCBs peacetime mission is intended to provide training for their mission in time of war. While productivity is a key issue with any organization, the peacetime deployments of NMCBs are not justified on cost competitiveness with the private sector, but on the basis that deployment construction projects provide the best combination of construction experience and mobilization training for dollar cost to the government. [Ref. 14]

Military activities receiving construction support from the NCF normally fund only the material costs, special equipment/tool costs and other direct costs to the NCF that are associated with the project. Fixed costs associated with the battalion, its TOA, and its deployment are not passed on to the activity. This includes personnel and travel costs. With this funding arrangement, NCF accomplishment of a project should always be cheaper for the activity than private sector accomplishment, where all direct, indirect and overhead costs must be recouped.

The true cost of NCF accomplishment does include all direct, indirect and overhead costs, but the output is more

than the completion of assigned construction projects. It includes the forward deployment of a Naval Mobile Construction Battalion, at all times, in each of five overseas locations. Two of those battalions, the Pacific and the Atlantic Alert Battalions, are ready and fully equipped to redeploy in support of contingency operations within six days of initial notification, with the construction equipment, tools, material and supplies necessary to provide construction support in a combat environment for 90 days without resupply (fuel, subsistence rations, and ammunition are based on a 15 day requirement). Additionally, each battalion is required to maintain the capability to redeploy, on 48 hours notice, an air detachment of 90 selected personnel with tools, equipment, and construction supplies for 30 days of self-sustained construction effort. [Ref. 3]

As such, it is inappropriate to attempt to justify the use of the NCF for overseas construction projects based on a comparison with private sector bids for similar work. Productivity comparisons between the NCF and the private sector would tend to ignore the differing missions of the two groups.

Nonetheless, construction productivity is an essential element of NMCB readiness. Since tasking can be expected to exceed available construction resources, particularly during wartime, construction productivity is always important. As in the construction industry, productivity issues in the NCF will be better addressed at the macro level, where decisions are made that have real impact on the amount of resources required to provide the necessary product. While efficiency on individual work tasks is important, the effectiveness with which the final product is provided is what ultimately counts.

III. CONSTRUCTION PRODUCTIVITY, ANALYSIS AND FINDINGS

The first section of this chapter discusses the rationale for using cost per manday (CPM) as a productivity measure, and presents the hypothesis to be tested. The data elements used in the analysis are developed, followed by an initial data refinement. The final analysis and findings are then presented, followed by a sensitivity analysis.

A. CPM AS A PRODUCTIVITY MEASURE

The intent of the analysis is the determination of the effect of NMCB minicomputer support on deployment construction productivity. An examination of existing reporting procedures failed to disclose an accepted productivity index in the NCF, in the traditional output over input form.

Since a limiting constraint in NMCB construction is that of direct labor construction personnel, a labor productivity measure is desired. The initial benefit analysis justifying the introduction of minicomputers in the NCF stated that one of the primary benefits of the computer would lie in the increase in efficiency made possible by better, more responsive scheduling. The analysis estimated that shorter construction times would result from an increase in productivity of the direct labor personnel. [Ref. 1: p. 12] This productivity change should therefore be revealed by an analysis of output per manday of direct labor.

Development of a productivity index for the NMCBs is hampered by the availability of data and the fact that it involves public sector construction. Typical to the public sector, the output does not have a sale price fixing its value on the open market, and the diversity associated with

the construction industry precludes assigning a price based on similar projects.

Given the above limitations, the "productivity ratio" developed is that of the material cost of the job (input as a proxy for output) over the mandays of direct labor charged to the job. This labor productivity ratio is termed "Cost per Manday" or CPM. The resulting hypothesis is restated from Figure 1.1 in Chapter I.

Hypothesis I: the dollar cost of material in place per direct labor manday is statistically different for construction projects accomplished since the introduction of minicomputers at the mainbody sites, than for those accomplished before their introduction.

B. DATA ELEMENTS USED IN ANALYSIS

1. Overview

Using data on projects at Diego Garcia, Rota, and Puerto Rico, measures of the cost per manday were developed as indicators of construction productivity. Time constraints precluded traveling to the 30th NCR in Guam to obtain and/or validate the necessary project data for Guam and Okinawa to allow inclusion of cost per manday analysis for projects at these locals. Accordingly, only projects at Puerto Rico, Diego Garcia, and Rota, Spain were used.

The data used in the CPM portion of the analysis is project-related instead of deployment-related. A total of six data elements were obtained for each project. Three data elements (cost, mandays, and project start date), were used to derive the dependent variable CPM for each project.

The CPM figures were analyzed using three nonmetric, categorical data elements or factors (Location, ADP, and Project Type) as the independent variables.

Each case was assigned a categorical confidence factor of from one to four indicating the degree of confidence in the data. This allowed inclusion of all projects in the data list, with subsequent decisions made on what to include in different analysis.

Figure 3.1 summarizes the data elements used, the coding for the nonmetric variables and the sources for the data. It is followed by a more detailed description of the data elements and the rationale for their use.

The primary sources of data are the Deployment Completion Reports (DCR), turnover letters (TOL) to the ROICC upon completion, Bills of Materials (BM), and Estimate at project Completion (EAC) reports listing material or special tool/equipment costs charged to the projects.

Table 6 in Appendix A provides a complete listing of the data and the refinement factors (index, deflater, and adjusted cost) used in the analysis.

2. CPM, the Dependent Variable

a. Input Measure, Direct Labor Mandays

Direct labor mandays for each project form the denominator of the productivity ratio. Mandays were not converted to a dollar value because data is not retained on the mandays by pay grade of the direct labor personnel. While a statistical average is used for costing the job on plant account records, use of it here would give a false sense of refinement, as it does not take into account the mix of wage rates applied to the project. Use of mandays in the denominator precludes a unitless index, however the resultant ratio would be directly related to one where the input was costed at a fixed, average rate per manday.

Data Element	Value	Source
Mandays	varies	DCR
(Project) Cost	varies	EAC,BM
Start	YY.MM	DCR
ADP	1 No ADP 2 0-25% w/ADP 3 25-75% w/ADP 4 75-99% w/ADP 5 100% w/ADP	DCR and CESO
Loc(ation)	1 Puerto Rico 2 Rota, Spain 5 Diego Garcia	DCR
Type (project)	1 Standard bldg, normal elect/ mechanical. 2 Warehouse, basic shop, w/ min. utilities or finish work. 3 Building w/ more than normal utilities, finish. 4 Electrical distribution systems. 5 Paving 6 Airfields. 7 Pier work. 8 Mechanical distribution systems. 0 other.	Subjective evaluation by author
Conf(idence)	0 Data looks valid. 1 Dates suspect. 2 Type suspect. 3 Date/type suspect. 4 Mandays/cost suspect.	Subjective evaluation by author

Figure 3.1 Data Elements Utilized in Analysis of CPM.

There were generally two possible sources of data for direct labor mandays, (1) the deployment completion report listing the completed project and (2) the turnover

letters from the battalion completing the project to the Resident Officer in Charge of Construction (ROICC), who is the project administrator that accepts the finished project from the battalion. Differences could occur where additional work was required on the project after issuance of the turnover letter. Where differences did occur, they were generally small and the higher manday value was taken on the assumption that subsequent work had been performed which was omitted from the other source.

b. Output Measure

(1) General. Output in the government sector is difficult to quantify in dollars because of the lack of competition in "selling" the product. Within the NCF, an acquisition cost is associated with each completed project, based on direct costs charged to the project funds (materials, special tools, equipment and tool rental charges, and any purchased services) plus statistical costs for military direct labor charged to the project, at a set rate per hour. All indirect and overhead labor costs are excluded, because NCF accounting procedures do not allocate them to the various jobs. In order to allocate these costs to the projects an allocation scheme would in all probability have to be based on direct labor hours. Thus it would tend to mask differences in job types and in the effect minicomputers have had on productivity. The effect of minicomputers on indirect/overhead labor costs is examined in the second productivity index, that of percent direct labor obtained on the deployment.

The direct and indirect costs associated with transportation, living/personnel costs, and the utilization of NCF construction equipment and tools are also excluded from the cost of construction in place. The exclusion of the latter two indirect costs has a more serious

effect on the validity of the analysis, because of the traditional inverse relationship between capital and labor as the factors of production. These costs must be excluded however, because of the lack of appropriate data. Equipment costs and usage are not charged to specific jobs in the NCF, if the equipment is part of the Table of Allowance. The equipment and tools are resources that are used to the extent they are available. Special equipment and tools that are not part of the Table of Allowance, but must be purchased or rented specifically for a particular job, are listed on the Bill of Materials and charged to the job the same as material. Purchased tools/equipment are turned over to the activity upon completion of the job. For the most part, the TOA covers the majority of tool/equipment requirements. For an overseas construction project, the excluded indirect and overhead costs could equal or exceed the direct material and labor costs. There is no established procedure for allocating these costs or actual direct labor costs to the projects. If such a procedure were available, it would provide an acquisition cost comparable to that obtained with construction through the private sector. Surrogate measures of output must be used, however, based upon available data.

The only data that approximates and would vary with the value of the finished output are the data on project material costs and direct labor. Since the intent is to identify changes in direct labor efficiency, inclusion of labor cost in the output measure would tend to minimize any change. Accordingly, the cost of material and special tools/equipment charged to the job, as a surrogate for the value of finished material in place, is chosen as the output measure.

(2) Material Costs. The output factor for the equation is the cost of material and special tools/equipment charged to the project. Actual cost information was sought

for each project. Analysis of the project Bill of Materials would provide this information, however complete BM files are not maintained on all projects after physical and financial completion, except for projects at Diego Garcia. (Physical completion is completion of all required work on a project. Financial completion entails the expensing of all obligations charged to project funds, with a resultant final cost. This final cost is referred to as the final "Estimate at Completion" (EAC), information of which is contained in the EAC report.)

For Rota and Puerto Rico projects, an alternate measure of material costs was required. The only information consistently available was the EAC report, showing total costs charged to project funds. Project funds are used for the purchase of all materials, and special tools, for equipment and tool rental, and for any other purchased services required in support of the project. Normally, only a small percentage of the project funds are expended for other than materials, although the percentage for some projects could be significant. It would be possible to segregate material costs by examination of the BMs, but their nonavailability makes reliance on the EAC reports a necessity. While the resultant productivity figures would be increased by the extent of other than material purchases included in the EAC, that distortion would be minimized in the analysis to the extent that its relative percent of the total EAC figure was constant from project to project. Grouping of projects accomplished with and without the computer assisted construction management further minimizes the effect. Materials and special tools/equipment charged to the project will be referred to as materials hereinafter.

Material costs were provided by Commander, 31st Naval Construction Regiment (COM31stNCR), Port Hueneme,

California for Diego Garcia projects, grouped into structural, mechanical, and electrical costs. The costs were taken from the file of BMs maintained for the Diego Garcia projects.

Twenty four EAC reports were available for examination at the headquarters of the Commander, Construction Battalions, Atlantic (COMCBLANT), Norfolk, Virginia, for Puerto Rico and Rota, Spain projects. A consolidated report was issued 6 times a year, beginning in May 1978; it included both Rota and Puerto Rico. Separate reports for Puerto Rico only were available back to November, 1976. In accordance with COMCBLANTINST 10370.1, project EAC figures are reported until all orders are expensed (i.e., the government pays the vendor based on a certified invoice received from the vendor) and then the project line item is dropped from the report. The last time the project is reported, the total EAC figure shown represents the final expensed costs. While the use of expensed costs has the advantage of not relying on the accuracy of the government's initial estimate for costs, its disadvantage lies in the time required to obtain expensed cost information. Time lags ranged over a year in some cases, between physical completion and financial completion.

In summary, project cost information is based on latest EAC reported costs, through July 1982 for Puerto Rico and Rota projects, and on Bill of Material totals for Diego Garcia projects. Cost figures were then adjusted to constant 1975 dollars to factor out the effects of inflation on CPM values. Figure 3.2 applies..

Engineering News Record material costs indexes were used to convert all costs to a base year of 1975, using the official January indices for a 20 city, nationwide average for the period 1975 through 1982 [Ref. 15 through 22].

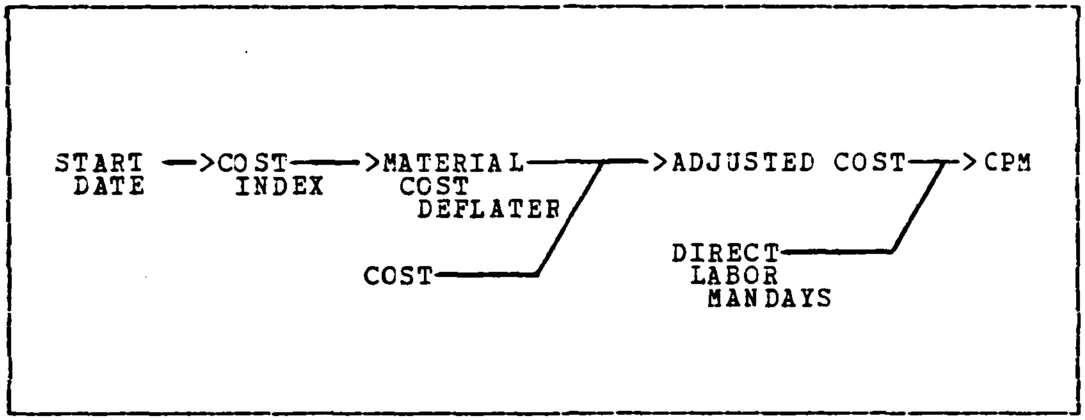


Figure 3.2 Derivation of CPM Values.

Because of "Buy American" requirements, material for NCF projects is procured by the Regiments in homeport, which are Port Hueneme, California for Pacific deployment sites and Diego Garcia, and Gulfport, Mississippi for Atlantic deployment sites. Department of Defense regulations require the maximum use of the Federal stock system. Accordingly only a small percentage of the material is procured directly from commercial sources. Due to the dispersion of procurement for the federal stock system, use of a nationwide material cost index is warranted. The cost trend is shown by figure 3.3.

Project start dates were taken as the material procurement dates, due to the lack of available data on when the material was actually procured. The effect of this is mitigated by the fact that the majority of the material is procured through the Federal stock system where prices are more stabilized.

A simple regression was run to develop monthly cost indices. The regression equation, based on ENR 20 City Nationwide Cost Indices is:

$$\text{Index} = -7549 + (112 \times \text{year})$$

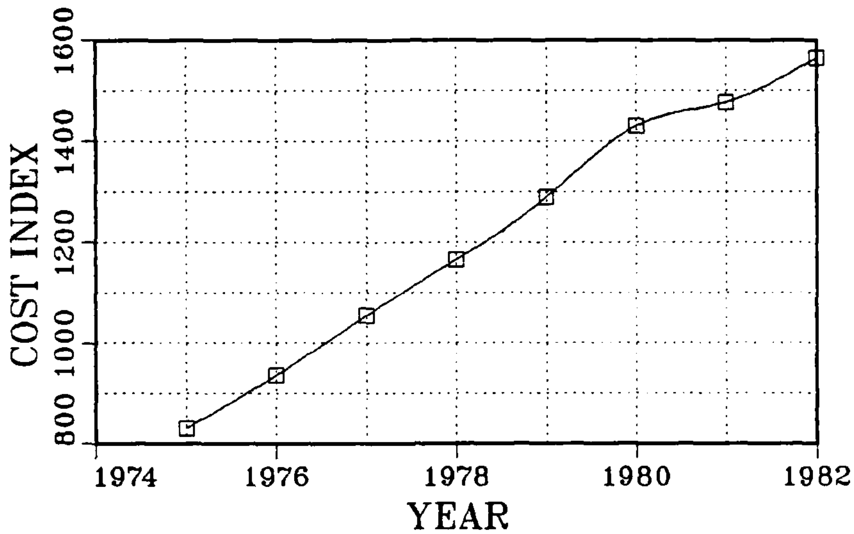


Figure 3.3 Official ENR January Material Cost Index.

where year is of the form xx.x (i.e., July 1980 is 80.5). The coefficient of determination (r squared) is 0.98. The base index for January 1975 (831.8) is divided by the index calculated above to provide a deflater which, when multiplied by the outyear cost, yields the adjusted cost in January 1975.

3. Independent Variables

a. ADP

Dates of introduction of the minicomputers were determined from Deployment Completion Reports and verified through discussions with knowledgeable personnel at the Naval Civil Engineering Support Office (CESO), Port Hueneme, California. They are listed in Table 1.

TABLE 1

Introduction of Mini-Computers, by Site

Deployment Site	Initial NMCB with ADP	Deployment start
Diego Garcia	NMCB 4	July 1978
Okinawa	3	June 1979
Guam	4	September 1979
Puerto Rico	40	May 1979
Rota, Spain	62	July 1979

The DCRs were reviewed to determine the percent complete on the various projects when the computer was introduced at the deployment site. Based on the percent complete, an ADP indicator value of between 1 and 5 was assigned, categorizing the extent of the project accomplished while computer assisted construction management was available. (See Figure 3.1.)

b. Location

Figure 3.1 shows the indicator values assigned to the locations used in the analysis.

c. Project Type

The choice of categories to group the projects was a subjective one, based upon a review of the wide variety of projects included in the study. The ideal situation would be to have a large number of identical projects at each site, with an equal number performed before and after introduction of the minicomputers. This is the crux of the problem regarding the study of construction productivity; seldom are any two projects exactly alike. Lacking identical projects, the projects were grouped based upon descriptive information and project photographs available in the DCRs into the types listed in figure 3.1.

d. Confidence

In the course of accumulating the data, it became apparent that not all data enjoyed the same confidence level. Examples include the subjective area of determination of project type, and relatively objective areas with multiple data sources and conflicting data, such as project costs or mandays. Rather than initially exclude such projects, they were included with a category factor assigned indicating the area(s) where the data was questionable, as shown in Figure 3.1.

4. <u>Initial Data Refinement</u>

Appendix A is a listing of the data values used in the analysis for the 151 projects for which data was available. Included are derived figures for the cost index (INDEX), deflater, adjusted cost (ADJ$), and cost per manday (CPM). Tables 7 through 9 in Appendix B show the distribution of project data compiled by location, and table 2 below is a summary for all locations by type and confidence level.

Table 3 arrays project types by confidence rating. Data for which the start or completion dates were suspect (CONF 1), the type was suspect (CONF 3 and/or 2), or the mandays or cost were suspect (CONF 4) were excluded from the analysis. There are only five projects with CONF = 1 or 2, four of which are projects of the type 6 or 9 which are excluded for reasons noted below. There were no projects with conf = 3, and conf = 4 was necessarily excluded because the primary data being analyzed was suspect for one reason or another.

In the analysis that follows, project types 1, 2, 3, 5, and 8 were utilized. Types 4, 6, and 7 were necessarily excluded because all projects were with ADP = 5. Type 9 was

TABLE 2

Summary Cross-tabulation of 151 CPM Projects

TYPE	COUNT / ROW PCT / COL PCT / TOT PCT	NO ADP 1	0-25% ADP 2	25-75% ADP 3	75-99% ADP 4	100% ADP 5	ROW TOTAL
		All Confidence Levels, All Locations					
STANDARD BLDG.	1	14	1	3	0	23	41
		34.1	2.4	7.3	0.0	56.1	27.2
		27.5	25.0	60.0	0.0	25.6	
		9.3	0.7	2.0	0.0	15.2	
BLDG, MINIMUM FINISH	2	11	0	0	0	16	27
		40.7	0.0	0.0	0.0	59.3	17.9
		21.6	0.0	0.0	0.0	17.8	
		7.3	0.0	0.0	0.0	10.6	
BUILDING WITH MORE THAN NORMAL FINISH/UTILITIES	3	8	1	0	1	9	19
		42.1	5.3	0.0	5.3	47.4	12.6
		15.7	25.0	0.0	100.0	10.0	
		5.3	0.7	0.0	0.7	6.0	
ELECTRICAL DISTRIBUTION SYSTEM	4	0	0	0	0	5	5
		0.0	0.0	0.0	0.0	100.0	3.3
		0.0	0.0	0.0	0.0	5.6	
		0.0	0.0	0.0	0.0	3.3	
PAVING	5	4	0	1	0	11	16
		25.0	0.0	6.3	0.0	68.8	10.6
		7.8	0.0	20.0	0.0	12.2	
		2.6	0.0	0.7	0.0	7.3	

Table 2

Summary Cross-tabulation of 151 CPM Projects (cont'd.)

All Confidence Levels, All Locations

TYPE	COUNT / ROW PCT / COL PCT / TOT PCT	NO ADP 1	0-25% ADP 2	25-75% ADP 3	75-99% ADP 4	100% ADP 5	ROW TOTAL
AIRFIELD	6	1	0	0	0	1	2
		50.0	0.0	0.0	0.0	50.0	1.3
		2.0	0.0	0.0	0.0	1.1	
		0.7	0.0	0.0	0.0	0.7	
PIER WORK	7	0	0	0	0	3	3
		0.0	0.0	0.0	0.0	100.0	2.0
		0.0	0.0	0.0	0.0	3.3	
		0.0	0.0	0.0	0.0	2.0	
MECHANICAL DISTRIBUTION SYSTEM	8	3	0	0	0	6	9
		33.3	0.0	0.0	0.0	66.7	6.0
		5.9	0.0	0.0	0.0	6.7	
		2.0	0.0	0.0	0.0	4.0	
OTHER	9	10	2	1	0	16	29
		34.5	6.9	3.4	0.0	55.2	19.2
		19.6	50.0	20.0	0.0	17.8	
		6.6	1.3	0.7	0.0	10.6	
	COLUMN TOTAL	51	4	5	1	90	151
		33.8	2.6	3.3	0.7	59.6	100.0

TABLE 3

Cross-tabulation of 151 CPM Projects, by Type and Confidence

TYPE (COUNT / ROW PCT / COL PCT / TOT PCT)		DATES SUSPECT 1	TYPE SUSPECT 2	BOTH SUSPECT 4	DATA VALID 5	ROW TOTAL
STANDARD BUILDING	1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	7 17.1 25.9 4.6	34 82.9 28.6 22.5	41 27.2
BUILDING WITH MINIMUM FINISH	2	0 0.0 0.0 0.0	0 0.0 0.0 0.0	7 25.9 25.9 4.6	20 74.1 16.8 13.2	27 17.9
BUILDING WITH MORE THAN NORMAL FINISH/UTILITIES	3	1 5.3 33.3 0.7	0 0.0 0.0 0.0	4 21.1 14.8 2.6	14 73.7 11.8 9.3	19 12.6
ELECTRICAL DISTRIBUTION SYSTEM	4	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	5 100.0 4.2 3.3	5 3.3
PAVING	5	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 12.5 7.4 1.3	14 87.5 11.8 9.3	16 10.6

Table 3

Cross-tabulation of 151 CPM Projects, by Type and Confidence (cont'd)

TYPE	COUNT / ROW PCT / COL PCT / TOT PCT	DATES SUSPECT 1	TYPE SUSPECT 2	BOTH SUSPECT 4	DATA VALID 5	ROW TOTAL
AIRFIELD	6	0 0.0 0.0 0.0	1 50.0 50.0 0.7	0 0.0 0.0 0.0	1 50.0 0.8 0.7	2 1.3
PIEF WORK	7	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 33.3 3.7 0.7	2 66.7 1.7 1.3	3 2.0
MECHANICAL DISTRIBUTION SYSTEM	8	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 22.2 7.4 1.3	7 77.8 5.9 4.6	9 6.0
OTHER	9	2 6.9 66.7 1.3	1 3.4 50.0 0.7	4 13.8 14.8 2.6	22 75.9 18.5 14.6	29 19.2
	COLUMN TOTAL	3 2.0	2 1.3	27 17.9	119 78.8	151 100.0

excluded because of the high standard deviation, however that was expected due to the project grouping of "other".

Projects with partial but not complete overlap with ADP (ADP 2,3,4) were initially included in the data list to provide a more complete accounting for the projects in the period covered by the analysis. They are excluded from the analysis however because of the unwarranted loss of degrees of freedom for the small increase in the number of projects covered. Of the 89 projects remaining after the above refinements, there were two projects with an ADP value of 2, three with a value of 3, and none with a value of 4.

This left 84 projects, which are summarized by TYPE and ADP in Table 4 below.

TABLE 4

Summary Cross-tabulation of 84 Projects

TYPE	COUNT / ROW PCT / COL PCT / TOT PCT	ADP: NO ADP 1	100% ADP 5	ROW TOTAL
STANDARD BUILDING	1	10 32.3 32.3 11.9	21 39.6 67.7 25.0	31 36.9
BUILDING WITH MINIMUM FINISH	2	9 29.0 45.0 10.7	11 20.8 55.0 13.1	20 23.8
BUILDING WITH MORE THAN NORMAL FINISH/UTILITIES	3	5 16.1 38.5 6.0	8 15.1 61.5 9.5	13 15.5
PAVING	5	4 12.9 30.8 4.8	9 17.0 69.2 10.7	13 15.5
MECHANICAL DISTRIBUTION SYSTEM	8	3 9.7 42.9 3.9	4 7.5 57.1 4.8	7 8.3
	COLUMN TOTAL	31 36.9	53 63.1	

These cases, which are used in the final analysis, are annotated in Table 6 in Appendix A. Tables 10 through 12 in Appendix B provide a cross-tabulation of project TYPE by ADP for each Location. Table 13 in Appendix B is a breakdown of CPM by TYPE, ADP, and LOC for the 84 projects used in the final analysis.

C. CPM ANALYSIS AND FINDINGS

For the analysis that follows in both this chapter and chapter IV, an interactive software program, Statistical Package for the Social Sciences (SPSS) was used for analysis of variance (ANOVA) and multiple classification analysis (MCA) calculations. Multiple contrast of means calculations were made utilizing a computer software system for data analysis by the Statistical Analysis System (SAS) Institute, Inc. Both were used on an IBM 3033 mainframe computer.

The standard analysis of variance is a statistical test to determine the probability of error if the difference in means between the two groups being analyzed are assumed to be equal. The hypothesis that the difference is zero is commonly referred to as the null hypothesis. The ANOVA determines the F statistic, and the significance of the F statistic, as a test of the null hypothesis. The significance level of the test is commonly taken to be 5 percent, which relates to a 95 percent confidence level. The significance level, or significance of F, is also called the Prob-value or p-value. It shows the extent to which the data supports the null hypothesis. P-values of 0.05 (5 percent) are equivalent to a confidence level of 95 percent that the null hypothesis is correct. Alternatively stated, there is a 5 percent chance that the null hypothesis is incorrect, given the data being examined.

The hypotheses being tested in this thesis, Hypothesis I and II in figures 1.1 and 1.2 of Chapter I, are the alternative hypotheses to the null hypotheses that the means of the indicators being examined are equal before and after introduction of the minicomputers. Acceptance of the null hypothesis requires the rejection of the alternative hypothesis. Alternatively, rejection of the null hypothesis requires acceptance of the alternative hypothesis. [Ref. 23]

1. Analysis

Using the 84 cases refined above, an initial breakdown of CPM values, by type, presence of ADP, and location, reveals no obvious pattern in changes in CPM values, based on the presence of ADP. See Table 13 in the Appendix. There are however, apparent differences between types of projects, with paving projects having twice the mean CPM as do the other four types.

A threeway Analysis of Variance (ANOVA) of the dependent variable CPM using the factors ADP, LOC, and TYPE shows that the independent variable TYPE had a statistically significant influence on CPM, while LOC and ADP did not. Higher order interactions were suppressed due to empty cells. See Figure 3.4 below. Examination of the multiple classification analysis shows a marked difference in the deviations from the grand mean between paving and the other types of construction.

A multiple contrast of means was then developed to determine which pairs are statistically different at the 95 percent confidence level. Paving (Type 5) is statistically different from three of the types of vertical construction, however, those three types of vertical construction are not statistically different from each other, as shown in Table 5.

```
* * * * * * * * * * A N A L Y S I S   O F   V A R I A N C E * * * * * * * * * *
                        CPM BY LOC, TYPE, ADP
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
```

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	17934.984	7	2562.141	3.148	0.006
LOC	756.899	2	378.449	0.465	0.630
TYPE	16887.469	4	4221.867	5.188	0.001
ADP	6.708	1	6.708	0.008	0.928
EXPLAINED	17934.984	7	2562.141	3.148	0.006
RESIDUAL	61847.516	76	813.783		
TOTAL	79782.500	83	961.235		

84 CASES WERE PROCESSED.
0 CASES (0.0 PCT) WERE MISSING.
DUE TO EMPTY CELLS OR A SINGULAR MATRIX,
HIGHER ORDER INTERACTIONS HAVE BEEN SUPPRESSED.

```
* * *   M U L T I P L E   C L A S S I F I C A T I O N   A N A L Y S I S   * * *
```

GRAND MEAN = 29.29

VARIABLE + CATEGORY	N	UNADJUSTED DEV'N	ETA	ADJUSTED FOR INDEPENDENTS DEV'N	BETA	ADJUSTED FOR INDEPENDENTS + COVARIATES DEV'N	BETA
LOC							
1 PUERTO RICO	29	-3.40		-4.57			
2 ROTA,SPAIN	31	4.07		2.29			
3 DIEGO GARCIA	24	-1.15		2.56			
			0.11		0.11		
TYPE							
1 STANDARD BLDG.	31	-9.14		-8.65			
2 BLDG, MIN. FINISH	20	-6.10		-5.32			
3 BLDG>FINISH-UTILITY	13	-0.91		-2.81			
5 PAVING	13	32.50		33.31			
8 MECH.DIST.SYS.	7	-0.76		-3.13			
			0.46		0.47		
ADP							
1 NO ADP	31	-2.17		-0.39			
5 100% ADP	53	1.27		0.23			
			0.05		0.01		
MULTIPLE R SQUARED					0.225		
MULTIPLE R					0.474		

Figure 3.4 **ANOVA on 84 CPM values, by Type, Location, and ADP.**

TABLE 5

Comparison of CPM Means, by Type

COMPARISONS SIGNIFICANT AT THE 0.05 LEVEL
ARE INDICATED BY '***'

TYPE COMPARISON		SIMULTANEOUS LOWER CONFIDENCE LIMIT	DIFFERENCE BETWEEN MEANS	SIMULTANEOUS UPPER CONFIDENCE LIMIT	
5	- 8	-4.037	33.255	70.548	
5	- 3	2.207	33.408	64.610	***
5	- 2	10.257	38.597	66.937	***
5	- 1	15.352	41.637	67.922	***
8	- 3	-37.140	0.153	37.446	
8	- 2	-29.593	5.341	40.275	
8	- 1	-24.907	8.381	41.670	
3	- 2	-23.152	5.188	33.529	
3	- 1	-18.056	8.228	34.513	
2	- 1	-19.775	3.040	25.855	

Accordingly, project types were grouped into horizontal construction (TYPE 5 or paving) and vertical construction (TYPE 1,2,3,8) for further analysis. This is consistent with the average CPM values for the various types of projects, noted in Table 13 of Appendix B. Grouping of projects into horizontal and vertical construction is logical based on the trades involved and complexity of work. The division of projects corresponds to the construction specialties of Buildings and Highways used by the Engineering News Record in annually categorizing the work of the top 400 construction contractors in the United States.

The factor LOC was reviewed further in an attempt to reduce the categories within the factor and hence the empty cells in the ANOVA matrix. Location categories were reduced from three to two with Diego Garcia listed separately because of the high operational priority assigned to jobs at that site, reflecting its strategic importance, and the other two sites, Puerto Rico and Rota, combined as otherwise normal deployment sites.

A threeway ANOVA, shown in figure 3.5 was run on the recoded data. While TYPE was again the only factor that had a statistically discernable effect on CPM, two way interactions were also significant; specifically the interaction between TYPE and ADP. ADP failed to show a statistically significant effect on CPM.

2. Findings

Hypothesis I, restated below, was tested by determining the significance of the F statistic for the factor ADP in an ANOVA testing the null hypothesis that the mean values of CPM are equal for the different values of ADP.

In this analysis, after accounting for the influences of project type and location, the significance of F is 0.88, indicating a 88 percent probability of error if the null hypothesis is rejected. Accordingly, the null hypothesis cannot be rejected and the mean CPM values for the projects accomplished with and without minicomputer support are assumed to be equal. This in turn requires the rejection of Hypothesis I.

> Hypothesis I: the dollar cost of material in place per direct labor manday is statistically different for construction projects accomplished since the introduction of minicomputers at the mainbody sites, than for those accomplished before their introduction.

```
* * * * * * * * * * A N A L Y S I S   O F   V A R I A N C E * * * * * * * * * *
                 CPM
              BY LCC, TYPE, ALP
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
```

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	16617.391	3	5539.129	7.428	0.000
LCC	305.489	1	305.489	0.410	0.524
TYPE	16284.191	1	16284.191	21.836	0.000
ADP	16.882	1	16.882	0.023	0.881
2-WAY INTERACTIONS	5741.668	3	1913.889	2.566	0.061
LOC TYPE	99.652	1	99.652	0.134	0.716
LOC ADP	47.512	1	47.512	0.064	0.801
TYPE ADP	5099.555	1	5099.555	6.838	0.011
EXPLAINED	22359.059	6	3726.510	4.997	0.000
RESIDUAL	57423.441	77	745.759		
TCTAL	79782.500	83	961.235		

84 CASES WERE PROCESSEL.
0 CASES (0.0 PCT) WERE MISSING.

Figure 3.5 ANOVA USING RECODED FACTORS LOC, TYPE, ADP.

D. CPM SENSITIVITY ANALYSIS

Analysis of any type presupposes a certain degree of accuracy in the data analyzed. The degree of accuracy readily obtained, and the degree of accuracy required are both difficult to determine a priori. Sensitivity analysis is an accepted technique for dealing with the accuracy question and its effect on the outcome of the analysis. The basic procedure is to determine the degree to which data critical to the analysis can vary before changing the outcome of the analysis. [Ref. 24].

Four variables were included in the final analysis of Hypothesis I. The sensitivity analysis that follows will focus on the development of the CPM values. TYPE, LOC, and ADP were excluded from the sensitivity analysis because the initial data refinement excluded projects where there was any question as to the validity of the values of these data elements, as indicated by the CONF factor assigned. The basic question which will be addressed is the accuracy required in deflating project cost figures to constant dollars. The Engineering News Record January Material Cost Index, 20 City National Average was used, with a necessary simplifying assumption that all costs were incurred on the start date of the projects. Treatment of cost inflation is a critical issue because of the 88 percent increase in the material cost index over the seven year period covered by the analysis (an average annual rate of 9.5 percent), and the fact that the minicomputers were introduced in the middle of that inflationary period.

Various average rates of inflation were used to determine at what point it would reduce the prob. value for ADP to 0.05 in the analysis of variance. That average annual rate was determined to be 2 percent, as compared to the average annual rate of 9.5 percent determined from the ENR index.

Some variation between the actual average inflation rate and that provided by the ENR 20 city national average is expected due to the difference in procurement practices between the federal government and that used to develop the index. It is reasonable to assume though that such an extreme downward bias is not probable.

IV. LEVEL OF EFFORT AS A PRODUCTIVITY INDICATOR

A. INTRODUCTION

The preceding chapter evaluated the more traditional labor productivity indicator, that of the cost of construction in place per direct labor manday. The second area of analysis is that of percent direct labor, which is a level of effort index more than a productivity index. It is an index that is used and commonly accepted within the NCF. The hypothesis to be tested is stated below, followed by a section discussing the use of percent direct labor as a performance measure and a review of the available data. Sections on the analysis, findings, and sensitivity analysis conclude the chapter.

Hypothesis II: the percent direct labor experienced by NMCBs since the introduction of minicomputers at main-body deployment sites is statistically different than that experienced prior to their introduction.

B. PERCENT DIRECT LABOR AS A PERFORMANCE MEASURE

Direct labor hours expended on a deployment and the resultant percent direct labor rate are aspects of battalion performance that receive high visibility both within the battalion and from its operational senior, the regiment. This is partially because construction project tasking is based to a large extent on the projected available manhours of direct labor. Available manhours of direct labor are a

function of the expected direct labor rate (normally 20-25 percent for the main body of the battalion), the projected average on-board count of personnel, and the number of workdays in the deployment.

Monthly deployment status reports provide estimated percent complete information on all projects. The reports are based on labor requirements for the project and are normally taken as the mandays of labor expended over the required mandays estimated for the project. Assuming that projects are completed in the estimated mandays, a graph of actual and projected cumulative mandays versus months of deployment, such as that shown in Figure 4.1, would provide an accurate measure of tasking accomplishment. In fact, a second vertical scale could be percent tasking completed, if the tasking was not changed during deployment, i.e., no projects added/deleted (an unlikely occurance), and manday requirements for original projects remain constant (a highly unlikely occurance).

If manning remained constant and cumulative mandays fell below the straight line, overall performance would, in lieu of extenuating circumstances such as adverse weather, material or equipment delays, military operations, or a change in priorities/tasking, be judged below par. If the cumulative manday figure was above the straight line, performance would be above par. Unfortunately, there is no clear distinction made between mandays required for a project and the total mandays expended on it. The two have generally been taken to be the same. It is worth noting that the Commander, Naval Mobile Construction Battalions, Atlantic Fleet instruction on timekeeping procedures did not have a cost account for rework [Ref. 25]. Similar timekeeping procedures were in effect in the Pacific. Accordingly, any rework required on a project due to unsatisfactory material or workmanship, or any other cause, gets

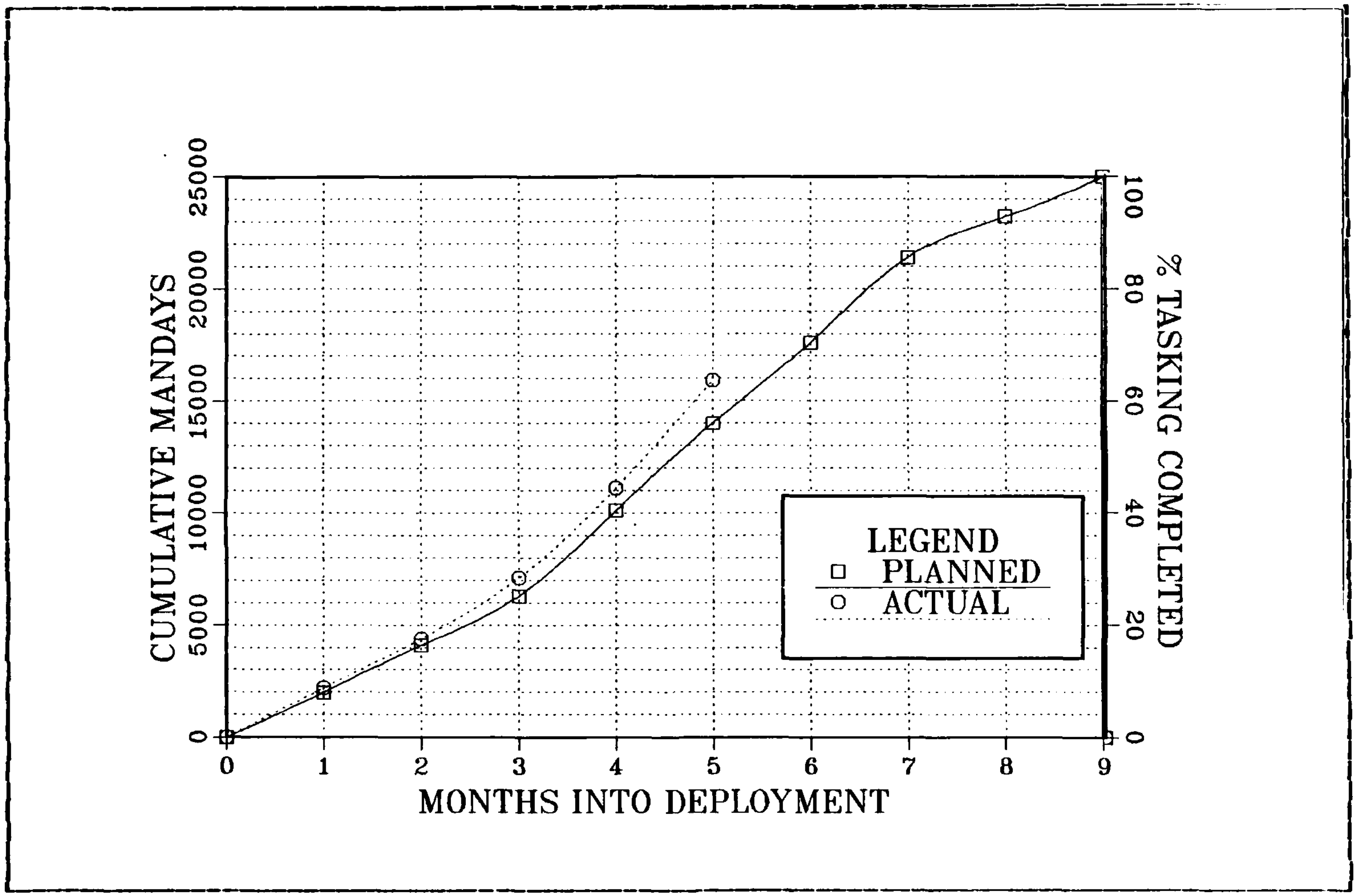


Figure 4.1 Tasking Accomplishment.

incorporated into total project manday and material cost figures, with no data available for distinguishing those costs. The difference considered in terms of total cost would be a valid measure of labor productivity.

A measure that allows for the variance in manning is the percentage direct labor figure. Assuming that projects were being completed within the direct labor manday budget allotted, the direct labor percentage measures the level of effort expended towards completion of tasking. See figure 4.2. If the percentage direct labor equals that used in the original tasking and average manning had been properly forecasted when the tasking was assigned, averaging that percent direct labor rate throughout the deployment would result in the 100 percent completion of the tasking. Specifically, the percent attainment of the planned cumulative percent direct labor rate would equal the percent of tasking completed. It is easy to understand why percent direct labor figures are closely monitored. They provide a single figure to monitor, which should vary little between battalions or deployments. Unlike tasked manday figures, it is relatively independent of specific manning levels, as long as that level remains unchanged. It does not require involved evaluation of progress on each job. If 24 percent direct labor is the goal and that is achieved, it is not unreasonable to expect that the tasking will have basically been completed. It must be recognized however, that some projects would have progressed further than planned; others correspondingly less.

The principle drawbacks on the use of percent direct labor are that (1) it is a measure of level of effort, not of accomplishment, (2) it de-emphasizes productivity by assuming it is both constant and correctly projected when original manday estimates were developed, and (3) there is no effective check inherent in its use which works to insure

Actual Cumulative Percent Direct Labor / Planned Percent Direct Labor	= Percent Tasking Completed
Example: 18% Direct Labor Attained / 24% Direct Labor Planned	= 75% of Tasking Completed

Figure 4.2 Percent Direct Labor/Tasking Completion.

proper labor classification. In fact, the attention given to percent direct labor figures would tend to insure that they are reported as high as possible. The performance measures used affect the reward system, which is intended to affect performance. The result which normally occurs is that the performance measure becomes performance per se, and efforts tend to be directed towards achieving good performance measures instead of good performance. [Ref. 26] Simply stated, the desired performance is completion of tasking, not attainment of high percent direct labor figures. The project supervisor is responsible for project accomplishment, but because of difficulties inherent in adjusting the required manday estimate on a project, it is often difficult to accurately gauge percentage complete. Minimally it requires an updating of the Critical Path Method (CPM) project management system. Time cards, however, are submitted weekly and provide immediate feedback on the level of effort (percent direct labor) being expended. As such, the system encourages that time be charged to direct labor, and not to indirect or overhead functions, in order to report good performance measures.

Despite its inherent limitations, percent direct labor is an established and accepted indicator of battalion

performance, with its limitations recognized within the NCF. Deployment data was analyzed accordingly in an effort to detect changes in percentage direct labor associated with the introduction of computer assisted construction management.

C. DATA ELEMENTS USED IN THE ANALYSIS

1. Overview

The primary sources of data for this portion of the analysis were the deployment completion reports (DCRs) completed by each battalion following the end of the deployment. The five year period 1977-1981 at the five mainbody deployment sites represented a total of 42 deployments by the 8 NMCBs. Forty of the DCRs were available for analysis.

The requirements for the preparation and submission of Deployment Completion Reports are delineated in a joint COMCBPAC/LANT instruction [Ref. 27]. It states in part "The Deployment Completion Report constitutes the primary single source of historical information with regard to battalion accomplishments and lessons learned on deployment." The instruction includes a standard format, topic areas and formated tables for statistical information on various aspects of the deployment, both personnel and project related. Despite the standardized guidance on preparation of the DCRs, one or more items of key information sought for this analysis could not be found in 70 percent of the forty DCRs reviewed.

Each deployment comprises one case. The ten variables compiled for the analysis are listed below, followed by an explanation of their derivation. The data values for the forty-two cases are listed in Appendix C. The variable BTNCODE identifies each case as to battalion, deployment site, and consecutive deployment at the site since the start

of the study. Tables 14 and 15 in Appendix C provides a breakdown of the factors assigned.

Dependent Variable

- MBACTDL Mainbody actual percent direct labor.

Independent Variables

- MBEM Average mainbody enlisted personnel.
- CONDUCT A factor that incorporates both awards given and disciplinary action taken during deployment.
- COTIBTN Commanding Officer time in battalion.
- MO%INT Percent Interium Repairs on the battalion's allowance of vehicles and heavy construction equipment.
- WTAVETOF Weighted average turnover factor of personnel.
- COMPUTER Computer availability: 0 for deployments at sites prior to introduction of the minicomputer, and 1 for subsequent deployments.
- LOC Location of the deployment site:
  1 Puerto Rico
  2 Rota, Spain
  3 Okinawa, Japan
  4 Guam
  5 Diego Garcia.
- DLPERS Average mainbody personnel assigned to direct labor.
- %LOSTDAY Lost workdays as a percent of total workdays.

2. <u>Dependent Variable, MBACTDL</u>

As addressed above, percent direct labor has been chosen as the dependent variable, in an attempt to determine if a statistical relationship can be identified between it and ADP. While percent direct labor data is available for the whole battalion, as well as the just the mainbody, the analysis is restricted to the mainbody because the majority of other data is available for the mainbody.

3. <u>Independent Variables</u>

a. MBEM

The total average onboard count of enlisted personnel at the mainbody site. This figure is available directly from the DCR.

b. Conduct

The DCR requires information on both the number of awards (medals, letters of commendation by higher authority (SLOC), and command letters of commendation (CLOC)) and the number of disciplinary cases (court martials (CM), and nonjudicial punishment (NJP)). These five data elements were combined as shown in figure 4.3.

$$\text{CONDUCT} = \frac{5 \text{ X Medal} + 3 \text{ X SLOC} + \text{CLOC}}{3 \text{ X CM} + \text{NJP}}$$

Figure 4.3 Conduct.

The factors are comparable between battalions of different on-board strengths, because each of the terms should be divided by the battalion strength, and that 1/battalion strength term cancels out of both the numerator and the denominator. The weighting factors provide relatively greater weights to the medal, SLOC and CM occurances.

This factor is utilized to take account of both the disruptive influence and the positive influence of those whose performance warrants special attention. Both are felt to influence productive effort. Larger values of CONDUCT indicate a relatively greater overall positive influence during a deployment.

c. COTIBTN

While it is not possible to utilize traditional learning curve techniques to account for the increasing contribution towards production that is expected to come from time in key billets, some recognition of that influence is possible through inclusion of a time in battalion factor for the Commanding Officer (COTIBTN). This factor equals the average current battalion experience by the individual in that billet. For a CO reporting aboard at the beginning of a 9 month deployment, COTIBTN = 4.5. For a CO completing a 24 month tour, being relieved at the end of the third month of a 9 month deployment, COTIBTN is figured as follows:

$$((3/9) \times (21 + 24)/2) + ((6/9) \times (0 + 6)/2) = 9.5$$

See figure 4.4. The Civil Engineer Corps Directory, NavFac P-1,. provided reporting dates for all officers.

d. MO%INT

This indicator is derived from the average of the interium repairs performed each month as a percentage of

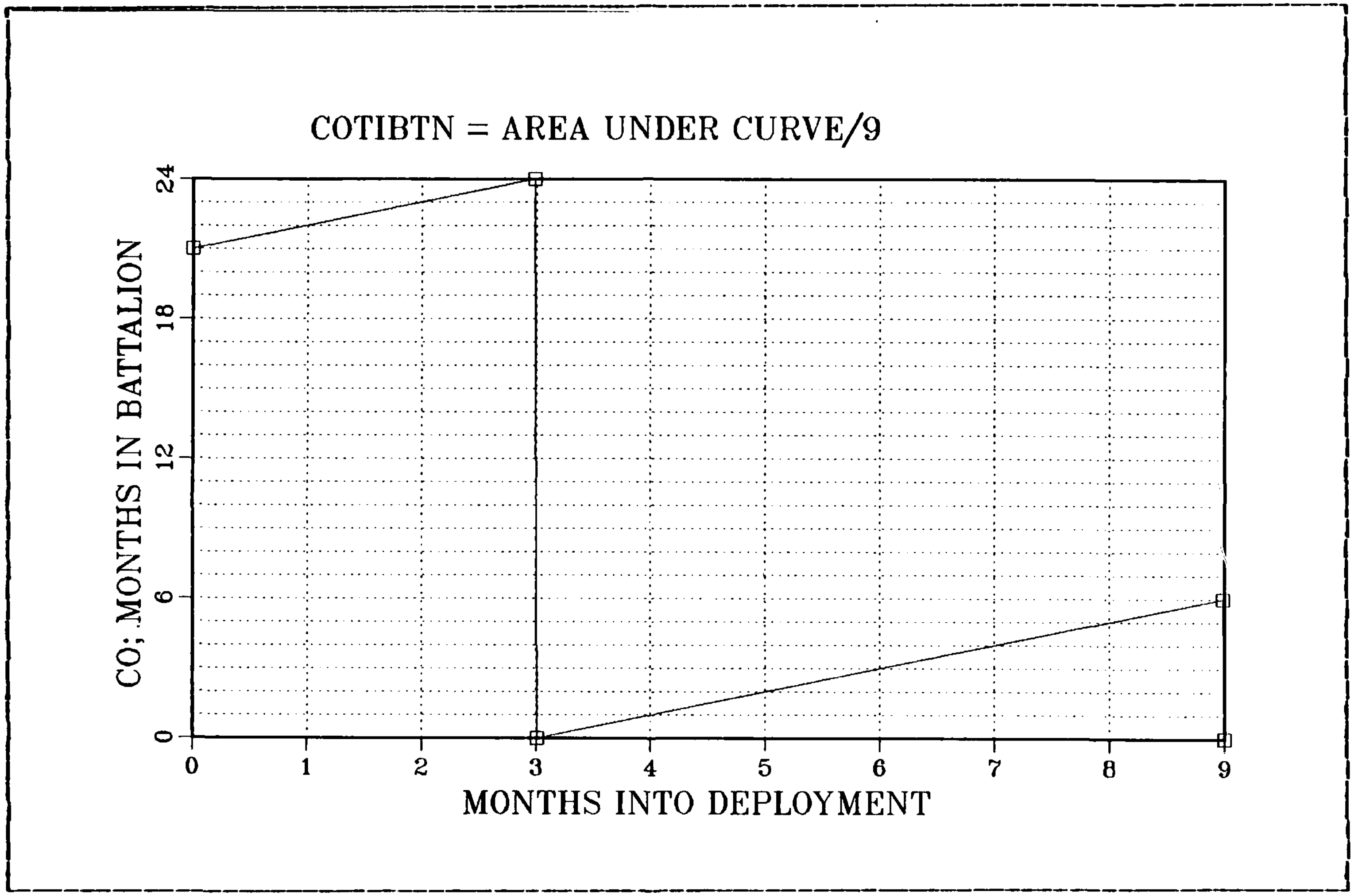


Figure 4.4 Derivation of COTIBTN.

the average CESE in service each month during the deployment. CESE is an acronym for Civil Engineer Support Equipment. It includes all vehicles and major construction equipment assigned to the battalion, excluding tools and minor equipment that is managed by the central tool room. Typical examples of CESE are jeeps, dump trucks, motor graders, backhoes, and wheeled or tracked tractors. A relatively higher MO%INT figure will have a more disruptive influence on production, as vehicles and/or equipment are out of service for unscheduled repairs. The information for this data element is taken from the DCR.

e. WTAVETOF

Personnel stability statistics are a required part of the DCR. Information is provided on losses and gains, by month of deployment, for the following categories: officers, E-7 to E-9, E-5 to E-6, E-1 to E-4. The WTAVETOF was computed as shown in figure 4.5.

Standard battalion peacetime manning for enlisted personnel by rate and rating, was obtained from reference 4. Enlisted tour lengths are available in the Enlisted Transfer Manual, reference 28. They range from 36 to 48 months. The most predominate sea tour is 36 months; this was taken as the standard, in computing the WTAVETOFs. Officer tour lengths have been a standard 24 months throughout the period of this study.

The turnover factor should equal 1.00; a greater number indicates higher than average turnover. This factor was included to provide recognition to the varying extent of turnover within different battalions, and to allow for recognition of its possible influence on production. Note that no allowance is made here for the relative influence of the different categories, i.e. a 110 percent WTAVETOF for chiefs (E-7 to E-9) would have the same value as a 110 percent WTAVETOF for junior enlisted personnel (E-1 to E-4).

Terms	
ATfr	Actual Transfers (in or out) during deployment.
AMT	Average Monthly Transfers. Calculated by multiplying the allowance of the category by 2 (transfer in and out) and dividing by the average tour length in months.
ETfr	Expected Transfers during deployment. This equals the AMT times the months of deployment.
TOF	ATfr/ETfr (Actual over Expected Transfers, during deployment)

For each of the four categories (officer, chiefs, E5-E6, and E1-E4) the TOF is calculated and then a weighted average (WTAVETCF) is determined by weighting each category according to its proportion of the total authorized peacetime manning.

Figure 4.5 Weighted Average Turnover Factor.

f. COMPUTER

Installation/initial operational dates for the minicomputer at each site were obtained the narrative portion of the applicable DCRs and confirmed with records at CESO. A dummy, categorical variable (0,1) was assigned based on the absence or presence respectively, of the mini-computer. Table 1 in Chapter Three shows installation dates for each site.

D. PERCENT DIRECT LABOR, ANALYSIS AND FINDINGS

1. Analysis

An analysis of variance using SPSS was performed on MBACTDL, with COMPUTER and LOC as factors, and COTIBTN, WTAVETOF, and MBEM as covariates. The three covariates were chosen from the possible seven because they provided a reasonable match between a need to include variables

representative of the differences between deployments, and a desire to maximize the number of cases utilized in the analysis. (As noted above, 70 percent of the forty cases studied had missing data for one or more of the eleven variables.) The analysis of variance procedure deletes cases if any of the variables are missing.

This initial ANOVA revealed that both LOC and MBEM had a statistically significant effect on MBACTDL. In addition there was a significant two way interaction between COMPUTER and LOC, as shown in Figure 4.6 below.

A separate analysis of variance was then performed on MBACTDL, with COMPUTER as a factor and the same covariates (COTIBTN, WTAVETOF, and MBEM) on the Diego Gracia deployments, on Okinawa deployments, and on deployments at the remaining sites as a group. This grouping of deployment sites follows the logic presented in the analysis of CPM in the previous chapter. Okinawa was treated separately because only one battalion, NMCB 3 (split into a Blue and a Gold team) rotated deployments there. This provided a greatly enhanced degree of continuity over that normally expected. Guam was included with Rota, Spain and Puerto Rico as an otherwise normal deployment site. Diego Garcia was treated separately because of the high operational priority placed on projects there. The results are shown in figures 4.7 through 4.9; in each case COMPUTER has a statistically significant effect on the MBACTDL rate achieved on the deployment, (i.e. significance of F of .05 or less.)

* * * * * * * * * * * A N A L Y S I S   O F   V A R I A N C E * * * * * * * * * * *

MBACTDL BY COMPUTER, LOC
WITH COTIBTN, WTAVETOF, MBEM

* *

SOURCE OF VARIATICN	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	520.614	8	65.077	4.056	0.006
COMPUTER	8.545	1	8.545	0.533	0.475
LCC	396.372	4	99.093	6.176	0.003
COTIBTN (COVAR)	0.003	1	0.003	0.000	0.989
WTAVETOF (COVAR)	7.203	1	7.203	0.449	0.511
MBEM (COVAR)	108.491	1	108.491	6.762	0.018
2-WAY INTERACTIONS	289.624	4	72.406	4.513	0.011
COMPUTER LOC	289.624	4	72.406	4.513	0.011
EXPLAINED	810.238	12	67.520	4.208	0.003
RESIDUAL	288.800	18	16.044		
TOTAL	1099.037	30	36.635		

38 CASES WERE PROCESSED.
7 CASES (18.4 PCT) WERE MISSING.

* * * M U L T I P L E   C L A S S I F I C A T I O N   A N A L Y S I S * * *

GRAND MEAN = 23.10

VARIABLE + CATEGORY	N	UNADJUSTED DEV'N	ETA	ADJUSTED FOR INDEPENDENTS DEV'N	BETA	ADJUSTED FOR INDEPENDENTS + COVARIATES DEV'N	BETA
CCMPUTER							
0 NO ADP	14	-0.58		0.09		-0.44	
1 ADP	17	0.48		-0.08		0.36	
			0.09		0.01		0.07
LOC							
1 PUERTO RICO	6	-1.52		-1.52		-2.17	
2 ROTA, SPAIN	4	-2.32		-2.29		-2.27	
3 OKINAWA	7	-3.24		-3.26		6.02	
4 GUAM	7	-0.60		-0.62		-1.19	
5 DIEGO GARCIA	7	6.47		6.50		-1.67	
			0.61		0.61		0.55
MULTIPLE R SQUARED					0.368		0.474
MUITIPLE R					0.607		0.688

Figure 4.6 ANOVA, WITH ALL LOCATIONS FACTORED SEPERATELY

```
* * * * * * * * * * A N A L Y S I S   O F   V A R I A N C E * * * * * * * * * *
               MEACTDL  BY COMPUTER
                        WITH COTIBTN, WTAVETOF, MBEM
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
                                        SUM OF                   MEAN         SIGNIF
SOURCE OF VARIATICN                    SQUARES      DF         SQUARE     F     OF F
MAIN EFFECTS                           210.374       4         52.593   2.594  0.090
   COMPUTER                            126.377       1        126.377   6.234  0.028
   COTIBTN   (COVAR)                    42.902       1         42.902   2.116  0.171
   WTAVETOF  (COVAR)                     3.978       1          3.978   0.196  0.666
   MBEM      (COVAR)                    37.118       1         37.118   1.831  0.201
EXPLAINED                              210.374       4         52.593   2.594  0.090
RESIDUAL                               243.281      12         20.273
TOTAL                                  453.655      16         28.353
     22 CASES WERE PROCESSED.
      5 CASES ( 22.7 PCT) WERE MISSING.

* * *   M U L T I P L E   C L A S S I F I C A T I O N   A N A L Y S I S   * * *

GRAND MEAN =     21.77                                                ADJUSTED FOR
                                                     ADJUSTED FOR     INDEPENDENTS
                                       UNADJUSTED    INDEPENDENTS     + COVARIATES
VARIABLE + CATEGORY          N         DEV'N  ETA    DEV'N   BETA     DEV'N   BETA
CCMPUTER
    0 NO ADP                 8          2.89          2.89             1.75
    1 ADP                    9         -2.57         -2.57            -1.55
                                              0.53           0.53              0.32
MULTIPLE R SQUARED                                           0.279             0.464
MULTIPLE R                                                   0.528             0.681
```

Figure 4.7   ANOVA For Puerto Rico, Rota, and Guam Deployments.

* * * * * * * * * * A N A L Y S I S   O F   V A R I A N C E * * * * * * * * * *

MBACTDL BY COMPUTER
WITH COTIBTN, WTAVETOF, MBEM

SOURCE OF VARIATICN	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	39.591	4	9.898	15.629	0.061
COMPUTER	24.107	1	24.107	38.066	0.025
COTIBTN (COVAR)	5.949	1	5.949	9.394	0.092
WTAVETOF (COVAR)	3.107	1	3.107	4.906	0.157
MBEM (COVAR)	6.428	1	6.428	10.149	0.086
EXPLAINED	39.591	4	9.898	15.629	0.061
RESIDUAL	1.267	2	0.633		
TOTAL	40.857	6	6.810		

9 CASES WERE PROCESSED.
2 CASES (22.2 PCT) WERE MISSING.

* * * M U L T I P L E   C L A S S I F I C A T I O N   A N A L Y S I S * * *

GRAND MEAN = 19.86

VARIABLE + CATEGORY	N	UNADJUSTED DEV'N	UNADJUSTED ETA	ADJUSTED FOR INDEPENDENTS DEV'N	ADJUSTED FOR INDEPENDENTS BETA	ADJUSTED FOR INDEPENDENTS + COVARIATES DEV'N	ADJUSTED FOR INDEPENDENTS + COVARIATES BETA
COMPUTER							
0 NO ADP	4	-1.61		-1.61		-1.16	
1 ADP	3	2.14		2.14		1.55	
			0.77		0.77		0.55
MUITIPLE R SQUAREL					0.590		0.969
MUITIPLE R					0.768		0.984

Figure 4.8 ANOVA, for Okinawa Deployments

```
* * * * * * * * * * A N A L Y S I S   O F   V A R I A N C E * * * * * * * * * *
               MBACTDL  BY COMPUTER
                        WITH COTIBTN, WTAVETOF, MBEM
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
                                     SUM OF                    MEAN              SIGNIF
SOURCE OF VARIATION                  SQUARES      DF          SQUARE        F      OF F
MAIN EFFECTS                         196.885       4          49.221    9.091    0.102
   COMPUTER                          140.014       1         140.014   25.859    0.037
   COTIBTN    (COVAR)                 21.157       1          21.157    3.907    0.187
   WTAVETOF   (COVAR)                 22.636       1          22.636    4.181    0.178
   MBEM       (COVAR)                 13.077       1          13.077    2.415    0.260
EXPLAINED                            196.885       4          49.221    9.091    0.102
RESIDUAL                              10.829       2           5.415
TOTAL                                207.714       6          34.619
      7 CASES WERE PROCESSED.
      0 CASES (  0.0 PCT) WERE MISSING.


* * *   M U L T I P L E   C L A S S I F I C A T I O N   A N A L Y S I S   * * *

GRAND MEAN =     29.57                                                 ADJUSTED FOR
                                                      ADJUSTED FOR     INDEPENDENTS
                                         UNADJUSTED   INDEPENDENTS     + COVARIATES
VARIABLE + CATEGORY          N           DEV'N  ETA   DEV'N   BETA     DEV'N   BETA
COMPUTER
    0 NO ADP                 2           -7.07        -7.07            -6.43
    1 ADP                    5            2.83         2.83             2.57
                                                0.82           0.82             0.75
MULTIPLE R SQUARED                                            0.674            0.948
MULTIPLE R                                                    0.821            0.974
```

Figure 4.9   ANOVA, for Diego Garcia Deployments.

2. Findings

Hypothesis II, restated below, is tested similarly to Hypothesis I by determining the significance of the F statistic of the factor COMPUTER in an analysis of variance that includes available and likely factors and covariates which might affect the dependent variable percent direct labor (MBACTDL). Hypothesis II is conversely related to the null hypothesis that the mean values of percent direct labor are equal, for deployments before and after the introduction of the minicomputers.

> Hypothesis II: the percent direct labor experienced by NMCBs since the introduction of minicomputers at mainbody deployment sites is statistically different than that experienced prior to their introduction.

Within the deployment groupings developed, the null hypothesis is safely rejected with less than five percent probability of being in error. Accordingly, Hypothesis II is accepted, with a 95 percent level of confidence.

The multiple classification analysis section that follows each analysis of variance shows the effect of the factor COMPUTER on the grand mean of the dependent variable, MBACTDL. In the case of Diego Garcia deployments, after adjusting for the independent factor and the covariates, MBACTDL figures averaged 23.14 (29.57 - 6.43) before introduction of the computer and 32.14 (29.57 + 2.57) after introduction of the computers, with an R squared value of 0.948. Percent direct labor figures for Okinawa deployments likewise went from an adjusted average of 18.7 to 21.41 with the introduction of the computer. (R squared = 0.969). The analysis which grouped Puerto Rico, Guam and Rota, Spain

together shows a decrease in the adjusted average percent direct labor, from 23.52 percent to 20.22 percent. This however has a much lower R squared value of 0.464.

E. PERCENT DIRECT LABOR SENSITIVITY ANALYSIS

In the above analysis, the main variable of concern is that of percent direct labor. It was noted that rework was reported as direct labor and that the reward system tended to emphasize attainment of high percent direct labor figures on monthly deployment status reports. The sensitivity analysis addresses how much error in the percent direct labor figures can be accommodated before the results of the analysis would change (i.e. significance of the F statistic for COMPUTER exceed 0.05)?

There are no apparent factors which would tend to bias the percent direct labor figures upward since the introduction of the computer. If anything, the tendency would be the opposite, as mandays must now be reported against specific activities on the project and reports are readily available showing actual versus planned mandays by activity. Increased use of these reports within the battalion would modify the reward system by giving the battalion chain of command weekly (or more frequently, if desired) reports on actual versus planned performance. This puts the crew leader in a position of having to justify overbudget expenditure of labor on each activity on a weekly basis. Before, with the practice of equating project percent complete with percent project mandays expended, the battalion basically had to reconcile the two only at the end of the deployment during turnover to the next battalion, assuming the project was not completed or there was a significant amount of mandays left out of the planned total requirement.

The question remains; how much error in the percent direct labor figures can be accommodated without affecting the analysis results? To determine this, the percent direct labor figures for deployments prior to introduction of the computer were changed by various percentages until the significance of the F statistic for the factor computer reached 0.05. Those percentages were 7 percent for Diego Garcia, 6 percent for Okinawa, and minus 4 percent for the otherwise normal deployment sites of Guam, Puerto Rico, and Rota. (Recall that in the Multiple Classification Analysis associated with the last ANOVA, introduction of the computer showed a decrease in percent direct labor figures.)

For Okinawa, if percent direct labor figures for the deployments prior to the introduction of the computer were all actually 6 percent higher than those reported (i.e. MBACTDL reported as 20 percent where the correct figure was 21.2 percent), the analysis would have shown a significance of F of .051 and Hypothesis II would have been rejected.

These variances are, in the opinion of the author, certainly within the realm of possibility, but given the natural bias upward before the introduction of the computer and downward after its introduction, they are not probable in the case of the Okinawa and the Diego Garcia deployments. In the case of the Puerto Rico, Rota, Guam group, if a reported average 23.5 percent direct labor figure for deployments prior to the introduction of minicomputers were actually 22.6 percent (i.e., the reported figures were 4 percent greater that actual figures), then an analysis using the correct figures would have shown no statistically discernable effect. Given the aforementioned natural biases, this is well within the realm of probability.

V. CONCLUSIONS AND RECOMMENDATIONS

A. COST PER MANDAY

1. Conclusions

The analysis of cost per manday as a productivity measure revealed no statistically discernable difference in cost per manday figures before and after introduction of the minicomputers, with the results relatively insensitive to the inflation rate used to deflate the cost figures to constant dollars. The premise in the initial Automated Data System Development Plan, that a fifteen percent reduction in construction durations would occur as a result of introduction of the minicomputers, was untestable due to a lack of recorded data on initial construction schedules.

The final analysis showed a statistically significant two way interaction between ADP and the recoded factor TYPE. A review of the available information fails to disclose any explanation for this interaction. The correlation of ADP with time may introduce a factor that is not properly accounted for in the analysis, possibly due to the method of deflating costs, an unidentified change in the mix of projects, or changes in battalion operational or construction procedures. An indepth focus on time correlated changes within the battalions might have resulted in the identification of an additional factor or factors which could have aided in the analysis of the effect of ADP on CPM. Such a focus was not within the scope of this study.

It must be recognized that CPM is not presented as an accepted, established, or validated productivity indicator. In fact, this is recognized as an inherent weakness in studying the effect of minicomputers or any other

management techniques in battalions; there is no generally accepted productivity index in use within the Naval Construction Force. It is noted however that this is not inconsistent with public sector construction in general. Both construction and public sector work, in general, have been outside the mainstream of productivity analysis due to difficulties in measuring output and determining comparable projects for comparison purposes.

2. Recommendations

An alternative approach to a typical productivity study could consider the standard in private sector construction, i.e., bringing the project in within the bid amount. Conceptually, projects could have a bid price established, including equipment and direct labor costs, at the start of the project and any changes to that price would be negotiated with the ROICC using established contract negotiation procedures. This would correspond closely to output as determined in the private sector, costed in dollars. Performance would then be measured based upon the inputs used to complete the project. Project management software is readily available for tracking this information against budgeted amounts. Whether this procedure would warrant the time and effort associated with it is uncertain. However the lack of an established, objective procedure to measure performance hampers the improvement of construction productivity, which is an important concern within the NCF.

B. PERCENT DIRECT LABOR

1. Conclusions

The conclusion of this analysis is that the introduction of minicomputers did have a statistically significant effect on the percent direct labor obtained on

deployment. An increase in percent direct labor was expected, and demonstrated at Diego Garcia and Okinawa, however the decrease found at the remaining sites is unexplained. The findings for the Puerto Rico, Rota, Guam group are sensitive to the accuracy of the percent direct labor figures reported to the extent that it is not felt that the findings should be considered conclusive. The time correlation of the introduction of the minicomputers, coupled with the lack of a control group makes it difficult to determine whether extraneous factors account for these differences. A more indepth focus on concurrent changes in operational and construction procedures might result in the identification of these factors, but none were apparent in the course of the study.

2. <u>Recommendations</u>

Considerations for further analysis should include a time series analysis of the three general categories of labor (direct, indirect, and overhead), coupled with a thorough evaluation of the extent of minicomputer use by major software application. The presence or absence of the computer, as used in this analysis, may have been an oversimplification given the varying degrees to which it may have been used.

C. SUMMARY

While this analysis has not been able to substantiate that minicomputers have had a significant effect on the productivity measure developed, a change in percent direct labor was shown. It is entirely plausible (if not probable) that the inability to show a statistically significant effect of minicomputers on productivity reflects more the inadequacy of the productivity index developed than the lack

of effect of the minicomputers. Further research is recommended in the development of an objective productivity index, even if it is project specific, to provide a more objective measure of construction project performance to the battalion. Realistic, quantifiable goals are critical to improving performance and sustaining that improvement. The magnitude of the construction put in place each year by the NCF warrants additional research in this area.

The question of the applicability of minicomputers to the mission of the NCF may be viewed as purely academic within the next decade, as their availability and capabilities increase and costs continue to drop. While this analysis treated computer availability as a binary factor, the state of the art in computer hardware and software tends to improve continuously. with relative differences between successive generations of equipment perhaps more significant than the presence/absence factor used here. Future studies should focus on productivity issues, the control and programming of labor and nonlabor resources, and the ability of the battalions to accurately plan and execute those plans, completing projects on schedule and within budget.

APPENDIX A

CONSTRUCTION PRODUCTIVITY DATA

TABLE 1

Construction Productivity Data

(Note: '*' indicates case used in final analysis.)

	PROJECT	MANDAY	COST	START	INDEX	ADP	TYPE	CONF	ADJ$	CPM	LOC	DEFLATOR
	1517.	251.	16832.	76.6	1030.195	1.	0.	0.	13590.	54.15	1.	0.807419
	1537.	677.	79048.	77.0	1075.000	1.	0.	0.	61165.	90.35	1.	0.773767
*	1577.	1390.	132845.	77.2	1097.398	1.	1.	0.	100693.	72.44	1.	0.757974
*	1582.	4366.	161343.	77.2	1097.398	1.	3.	0.	122294.	28.01	1.	0.757974
	1587.	700.	10576.	77.2	1097.398	1.	1.	4.	8016.	11.45	1.	0.757974
*	1588.	1441.	72992.	77.5	1131.000	1.	1.	0.	53682.	37.25	1.	0.735455
*	30.	3266.	182576.	76.7	1041.398	1.	5.	0.	145830.	44.65	1.	0.798733
	60.	3762.	47880.	76.2	985.398	1.	1.	4.	40417.	10.74	1.	0.844125
*	469.	25794.	927772.	77.0	1075.000	1.	1.	0.	717880.	27.83	1.	0.773767
*	6401.	318.	14760.	80.6	1478.195	5.	5.	0.	8306.	26.12	1.	0.562713
*	402.	320.	13833.	80.2	1433.398	5.	1.	0.	8027.	25.09	1.	0.580299
*	406.	299.	3260.	78.1	1198.195	1.	2.	0.	2263.	7.57	1.	0.694211
	408.	857.	9562.	78.2	1209.398	1.	0.	4.	6577.	7.67	1.	0.687780
*	411.	981.	66132.	81.6	1590.195	5.	2.	0.	34592.	35.26	1.	0.523080
	416.	561.	21272.	78.6	1254.195	1.	1.	4.	14108.	25.15	1.	0.663214
*	418.	145.	1604.	78.4	1231.797	1.	2.	0.	1083.	7.47	1.	0.675273
*	801.	3603.	103776.	77.2	1097.398	1.	5.	0.	78660.	21.83	1.	0.757974
	7401.	539.	17132.	81.1	1534.195	5.	0.	0.	9289.	17.23	1.	0.542173
	402.	580.	14065.	79.7	1377.398	5.	1.	4.	8494.	14.64	1.	0.603892
	404.	316.	11282.	77.7	1153.398	1.	2.	4.	8136.	25.75	1.	0.721173
*	407.	344.	11281.	78.2	1209.398	1.	2.	0.	7759.	22.55	1.	0.687780
*	408.	341.	11439.	80.0	1411.000	5.	1.	0.	6743.	19.78	1.	0.589511
*	410.	120.	6738.	78.7	1265.398	1.	2.	0.	4429.	36.91	1.	0.657342
	411.	326.	11640.	80.2	1433.398	5.	0.	0.	6755.	20.72	1.	0.580299

Table 6

Construction Productivity Data (cont'd.)

PROJECT	MANDAY	COST	START	INDEX	ADP	TYPE	CONF	ADJ$	CPM	LOC	DEFLATOR
412.	74.	1731.	78.7	1265.398	1.	0.	0.	1138.	15.38	1.	0.657342
* 417.	524.	5725.	78.0	1187.000	1.	1.	0.	4012.	7.66	1.	0.700758
* 413.	740.	46806.	82.1	1646.195	1.	2.	0.	23650.	31.96	1.	0.505286
8421.	415.	10506.	79.1	1310.195	1.	0.	0.	6670.	16.07	1.	0.634867
8801.	2228.	128051.	78.0	1187.000	3.	5.	0.	89733.	40.28	1.	0.700758
* 803.	1040.	22649.	78.3	1220.598	1.	2.	0.	15435.	14.84	1.	0.681469
* 804.	1307.	19996.	78.9	1287.797	1.	2.	0.	12916.	9.88	1.	0.645909
* 805.	3640.	76382.	79.2	1321.398	5.	1.	0.	48081.	13.21	1.	0.629484
* 806.	1331.	21385.	80.7	1489.398	5.	1.	0.	11943.	8.97	1.	0.558480
* 807.	401.	9970.	81.6	1590.195	5.	1.	0.	5215.	13.01	1.	0.523080
815.	14583.	430642.	79.2	1321.398	5.	0.	0.	271082.	18.59	1.	0.629484
816.	765.	104038.	80.2	1433.398	5.	5.	4.	60373.	78.92	1.	0.580299
* 817.	1000.	24979.	78.8	1276.598	1.	1.	0.	16276.	16.28	1.	0.651576
* 819.	1315.	51036.	80.0	1411.000	5.	2.	0.	30086.	22.88	1.	0.589511
822.	1316.	129021.	81.2	1545.398	5.	7.	0.	69445.	52.77	1.	0.538243
* 823.	1770.	107839.	80.7	1489.398	5.	5.	0.	60226.	34.03	1.	0.558480
* 825.	1370.	247572.	81.3	1556.598	5.	5.	0.	132295.	96.57	1.	0.534370
* 9831.	2324.	50537.	79.3	1332.598	5.	1.	0.	31545.	13.57	1.	0.624194
* 843.	1628.	80768.	81.0	1523.000	5.	5.	0.	44112.	27.10	1.	0.546159
1460.	1331.	75363.	81.0	1523.000	5.	0.	4.	41160.	30.92	1.	0.546159
* 1465.	521.	13949.	81.6	1590.195	5.	1.	0.	7296.	14.00	1.	0.523080
*69880.	817.	22067.	81.6	1590.195	5.	1.	0.	11543.	14.13	1.	0.523080
* 105.	2058.	60637.	80.2	1433.398	5.	3.	0.	35188.	17.10	2.	0.580299
106.	9697.	218747.	77.6	1142.195	3.	1.	4.	159302.	16.43	2.	0.728247
110.	1417.	55318.	78.1	1198.195	2.	3.	0.	38402.	27.10	2.	0.694211
* 114.	517.	11607.	76.9	1063.797	1.	5.	0.	9076.	17.55	2.	0.781916
* 116.	1489.	32219.	80.2	1433.398	5.	2.	0.	18697.	12.56	2.	0.580299
117.	1501.	47815.	80.5	1467.000	5.	2.	4.	27111.	18.06	2.	0.567007
128.	874.	40799.	79.8	1388.598	5.	3.	4.	24439.	27.96	2.	0.599021
* 129.	1306.	45172.	76.9	1063.797	1.	8.	0.	35321.	27.04	2.	0.781916
* 139.	379.	8779.	76.9	1063.797	1.	8.	0.	6864.	18.11	2.	0.781916
15.	14082.	497035.	77.6	1142.195	2.	1.	0.	361964.	25.70	2.	0.728247
* 23.	3825.	107969.	77.1	1086.195	1.	3.	0.	82682.	21.62	2.	0.765792
* 41.	439.	4050.	76.8	1052.598	1.	3.	0.	3200.	7.29	2.	0.790235
* 446.	1390.	5815.	76.9	1063.797	1.	1.	0.	4547.	3.27	2.	0.781916
447.	1087.	60580.	81.2	1545.398	5.	7.	4.	32607.	30.00	2.	0.538243
* 450.	1688.	19082.	77.6	1142.195	1.	1.	0.	13896.	8.23	2.	0.728247

Table 6

Construction Productivity Data (cont'd.)

	PROJECT	MANDAY	COST	START	INDEX	ADP	TYPE	CONF	ADJ$	CPM	LOC	DEFLATOR
*	462.	3754.	115229.	75.9	951.797	1.	3.	0.	100702.	26.83	2.	0.873926
*	502.	2994.	279499.	76.5	1019.000	1.	8.	0.	228152.	76.20	2.	0.816290
*	6850.	750.	20040.	80.2	1433.398	5.	8.	0.	11629.	15.51	2.	0.580299
*	6423.	722.	32436.	80.5	1467.000	5.	2.	0.	18391.	25.47	2.	0.567007
*	6431.	693.	11621.	81.5	1579.000	5.	1.	0.	6122.	8.83	2.	0.526789
	6837.	4084.	255638.	77.6	1142.195	2.	0.	0.	186167.	45.58	2.	0.728247
	6838.	2930.	173814.	78.3	1220.598	1.	0.	0.	118449.	40.43	2.	0.681469
	6847.	277.	20223.	77.7	1153.398	1.	3.	4.	14584.	52.65	2.	0.721173
*	6852.	1236.	63056.	78.2	1209.398	1.	2.	0.	43369.	35.09	2.	0.687780
	7880.	251.	21477.	80.2	1433.398	5.	4.	0.	12463.	49.65	2.	0.580299
	7882.	1473.	40997.	77.7	1153.398	2.	0.	0.	29566.	20.07	2.	0.721173
	7883.	379.	21097.	79.6	1366.195	5.	4.	0.	12845.	33.89	2.	0.608844
	7886.	2886.	170207.	80.2	1433.398	5.	7.	0.	98771.	34.22	2.	0.580299
*	7891.	1147.	77333.	79.5	1355.000	5.	5.	0.	47473.	41.39	2.	0.613874
*	7892.	354.	149003.	79.5	1355.000	5.	5.	0.	91469.	258.39	2.	0.613874
*	8448.	480.	13464.	78.2	1209.398	1.	1.	0.	9260.	19.29	2.	0.687780
	8893.	1128.	57046.	79.5	1355.000	5.	0.	0.	35019.	31.05	2.	0.613874
*	9400.	1134.	44215.	79.5	1355.000	5.	2.	0.	27142.	23.94	2.	0.613874
*	9406.	820.	7435.	79.5	1355.000	5.	1.	0.	4564.	5.57	2.	0.613874
*	9408.	308.	11472.	80.4	1455.797	5.	2.	0.	6555.	21.28	2.	0.571371
*	9409.	875.	34193.	80.5	1467.000	5.	1.	0.	19388.	22.16	2.	0.567007
	9898.	1813.	227715.	81.5	1579.000	5.	4.	0.	119958.	66.17	2.	0.526789
	9901.	834.	51065.	81.1	1534.195	5.	4.	0.	27686.	33.20	2.	0.542173
*	9902.	1400.	37842.	81.5	1579.000	5.	3.	0.	19935.	14.24	2.	0.526789
*	9903.	369.	42899.	81.0	1523.000	5.	5.	0.	23430.	63.50	2.	0.546159
	9905.	950.	22027.	80.2	1433.398	5.	0.	0.	12782.	13.45	2.	0.580299
	9981.	1046.	23029.	82.2	1657.398	5.	2.	4.	11558.	11.05	2.	0.501871
*	9935.	457.	65996.	80.8	1500.598	5.	5.	0.	36582.	80.05	2.	0.554312
*	9950.	2221.	97349.	81.2	1545.398	5.	1.	0.	52397.	23.59	2.	0.536243
	9975.	210.	9960.	81.3	1556.598	5.	0.	0.	5322.	25.34	2.	0.534370

Table 6

Construction Productivity Data (cont'd.)

PROJECT	MANDAY	COST	START	INDEX	ADP	TYPE	CONF	ADJ$	CPM	LOC	DEFLATOR
* 9980.	1556.	57611.	81.7	1601.398	5.	1.	0.	29924.	19.23	2.	0.519421
9984.	552.	292595.	81.6	1590.195	5.	6.	0.	153051.	277.27	2.	0.523080
* 16.	457.	34343.	81.2	1545.398	5.	5.	0.	18485.	40.45	2.	0.538243
43.	225.	24459.	80.8	1500.598	5.	0.	0.	13558.	60.26	2.	0.554312
45.	433.	17508.	81.5	1579.000	5.	0.	0.	9223.	21.30	2.	0.526789
* 436.	296.	5608.	81.9	1623.797	5.	1.	0.	2873.	9.71	2.	0.512256
* 430.	460.	39507.	82.2	1657.398	5.	2.	0.	19827.	43.10	2.	0.501871
431.	378.	36685.	82.2	1657.398	5.	2.	4.	18411.	48.71	2.	0.501871
* 1825.	325.	17875.	82.2	1657.398	5.	1.	0.	8971.	27.60	2.	0.501871
1847.	91.	2121.	82.2	1657.398	5.	0.	0.	1064.	11.70	2.	0.501871
21.	849.	801500.	77.2	1097.398	1.	0.	1.	607516.	715.57	5.	0.757974
* 28.	8594.	505400.	75.0	851.000	1.	3.	0.	493997.	57.48	5.	0.977438
30.	19712.	788300.	75.0	851.000	1.	3.	1.	770514.	39.09	5.	0.977438
42.	na	76100.	75.0	851.000	1.	1.	1.	74383.	na	5.	0.977438
47.	na	106500.	76.4	1007.797	na	3.	0.	87901.	na	5.	0.825365
48.	na	89300.	75.0	851.000	1.	1.	1.	87285.	na	5.	0.977438
49.	4252.	90200.	76.3	996.598	1.	3.	4.	75284.	17.71	5.	0.834639
* 50.	6149.	292100.	76.4	1007.797	1.	1.	0.	241089.	39.21	5.	0.825365
51.	2862.	64900.	75.0	851.000	1.	1.	4.	63436.	22.16	5.	0.977438
* 52.	12546.	209100.	75.0	851.000	1.	1.	0.	204382.	16.29	5.	0.977438
53.	2724.	104800.	76.7	1041.398	1.	0.	4.	83707.	30.73	5.	0.798733
58.	1306.	106600.	76.7	1041.398	1.	0.	0.	85145.	65.20	5.	0.798733
5964.	7020.	112800.	79.2	1321.398	5.	0.	0.	71006.	10.11	5.	0.629484
6253.	2642.	272300.	76.4	1007.797	1.	2.	2.	224747.	85.07	5.	0.825365
6276.	2563.	321900.	76.6	1030.195	1.	0.	2.	259908.	101.41	5.	0.807419
6296.	345.	11000.	78.5	1243.000	5.	8.	2.	7361.	21.34	5.	0.669187
* 6521.	4123.	63000.	78.2	1209.398	5.	2.	0.	43330.	10.51	5.	0.687780
* 6614.	1880.	38400.	78.7	1265.398	5.	3.	0.	25242.	13.43	5.	0.657342
6815.	11086.	1810000.	76.4	1007.797	1.	5.	2.	1493909.	134.76	5.	0.825365

Table 6

Construction Productivity Data (cont'd.)

PROJECT	MANDAY	COST	START	INDEX	ADP	TYPE	CONF	ADJ$	CPM	LOC	DEFLATOR
*29882.	4028.	263000.	76.8	1052.598	1.	5.	0.	207832.	51.60	5.	0.790235
6830.	16680.	1294099.	76.8	1052.598	3.	0.	0.	1022643.	61.31	5.	0.790235
6831.	5908.	373700.	77.8	1164.598	4.	3.	4.	266911.	45.18	5.	0.714238
* 6835.	11510.	233800.	77.8	1164.598	5.	8.	0.	166989.	14.51	5.	0.714238
6836.	623.	300500.	78.5	1243.000	5.	0.	0.	201091.	322.78	5.	0.669187
6840.	9744.	693500.	76.6	1030.195	3.	1.	0.	559945.	57.47	5.	0.807419
6841.	9646.	233200.	76.8	1052.598	3.	1.	0.	184283.	19.10	5.	0.790235
* 6842.	8605.	233800.	76.9	1063.797	5.	1.	0.	182812.	21.24	5.	0.781916
6846.	7348.	239300.	78.9	1287.797	5.	1.	4.	154566.	21.04	5.	0.645909
* 6847.	7982.	346100.	78.9	1287.797	5.	1.	0.	223549.	28.01	5.	0.645909
* 6860.	2229.	104300.	78.3	1220.598	5.	3.	0.	71077.	31.89	5.	0.681469
* 6862.	4586.	172600.	77.2	1097.398	1.	2.	0.	130826.	28.53	5.	0.757974
* 6863.	2974.	93600.	78.7	1265.398	5.	2.	0.	61527.	20.69	5.	0.657342
* 6870.	7966.	406400.	78.5	1243.000	5.	3.	0.	271958.	34.14	5.	0.669187
* 6872.	351.	8000.	78.9	1287.797	5.	3.	0.	5167.	14.72	5.	0.645909
*76877.	7343.	321000.	78.5	1243.000	5.	8.	0.	214809.	29.25	5.	0.669187
6877.	2435.	222300.	79.8	1388.598	5.	0.	1.	133162.	54.69	5.	0.599021
6877.	10326.	544700.	80.4	1455.797	5.	0.	0.	311226.	30.14	5.	0.571371
* 6880.	9938.	660000.	78.3	1220.598	5.	2.	0.	449770.	45.26	5.	0.681469
6882.	2480.	90200.	78.7	1265.398	5.	4.	0.	59292.	23.91	5.	0.657342
* 8843.	9147.	337400.	79.6	1366.195	5.	1.	0.	205424.	22.46	5.	0.608844
* 8844.	9359.	391400.	80.5	1467.000	5.	1.	0.	221927.	23.71	5.	0.567007
* 8845.	12205.	419400.	79.6	1366.195	5.	1.	0.	255349.	20.92	5.	0.608844
* 8848.	10755.	419400.	80.5	1467.000	5.	1.	0.	237803.	22.11	5.	0.567007
8885.	1730.	63200.	80.5	1467.000	5.	0.	4.	35835.	20.71	5.	0.567007
* 8887.	2464.	83000.	80.5	1467.000	5.	8.	0.	47062.	19.10	5.	0.567007
8888.	1449.	62300.	78.8	1276.598	5.	5.	4.	40593.	28.01	5.	0.651576
815.	760.	1881000.	80.5	1467.000	5.	0.	0.	1066540.	1403.34	5.	0.567007
820.	4735.	84700.	79.8	1388.600	5.	2.	4.	50737.	10.72	5.	0.599020
* 820.	1515.	21500.	80.5	1467.000	5.	2.	0.	12191.	8.05	5.	0.567007
820.	na	3300.	80.5	1467.000	5.	2.	0.	1871.	na	5.	0.567007
820.	6154.	91400.	80.5	1467.000	5.	8.	4.	51824.	8.42	5.	0.567007
868.	380.	41800.	80.5	1467.000	5.	2.	4.	23701.	62.37	5.	0.567007
* 961.	1756.	215700.	80.5	1467.000	5.	3.	0.	122303.	69.65	5.	0.567007
* 1821.	11107.	637000.	80.5	1467.000	5.	3.	0.	361184.	32.52	5.	0.567007

APPENDIX B

TABULATIONS RELATING TO PRELIMINARY CPM ANALYSIS

TABLE 7

Cross-tabulation of Initial Puerto Rico Projects

TYPE	COUNT / ROW PCT / COL PCT / TOT PCT	NO ADP 1	ADP 25-75% ADP 3	100% ADP 5	ROW TOTAL
1 STANDARD BUILDING	COUNT	8	0	9	17
	ROW PCT	47.1	0.0	52.9	37.0
	COL PCT	33.3	0.0	42.9	
	TOT PCT	17.4	0.0	19.6	
2 BUILDING w/ MINIMUM FINISH, UTILITIES	COUNT	8	0	2	10
	ROW PCT	80.0	0.0	20.0	21.7
	COL PCT	33.3	0.0	9.5	
	TOT PCT	17.4	0.0	4.3	
3 BUILDING w/ GREATER FINISH, OR UTILITIES	COUNT	1	0	0	1
	ROW PCT	100.0	0.0	0.0	2.2
	COL PCT	4.2	0.0	0.0	
	TOT PCT	2.2	0.0	0.0	
5 PAVING	COUNT	2	1	5	8
	ROW PCT	25.0	12.5	62.5	17.4
	COL PCT	8.3	100.0	23.8	
	TOT PCT	4.3	2.2	10.9	
7 PIER WORK	COUNT	0	0	1	1
	ROW PCT	0.0	0.0	100.0	2.2
	COL PCT	0.0	0.0	4.8	
	TOT PCT	0.0	0.0	2.2	
9 OTHER	COUNT	5	0	4	9
	ROW PCT	55.6	0.0	44.4	19.6
	COL PCT	20.8	0.0	19.0	
	TOT PCT	10.9	0.0	8.7	
COLUMN TOTAL		24	1	21	46
		52.2	2.2	45.7	100.0

TABLE 8

Cross-tabulaticn of Initial Projects at Rota, Spain

TYPE	COUNT / ROW PCT / COL PCT / TOT PCT	NO ADP 1	0-25% ADP 2	25-75% ADP 3	100% ADP 5	ROW TOTAL
STANDARD BUILDING	1	3 25.0 23.1 5.5	1 8.3 25.0 1.8	1 8.3 100.0 1.8	7 58.3 18.9 12.7	12 21.8
BUILDING W/ MINIMUM FINISH, UTILITIES	2	1 11.1 7.7 1.8	0 0.0 0.0 0.0	0 0.0 0.0 0.0	8 88.9 21.6 14.5	9 16.4
BUILDING W/ GREATER FINISH, OR UTILITIES	3	4 50.0 30.8 7.3	1 12.5 25.0 1.8	0 0.0 0.0 0.0	3 37.5 8.1 5.5	8 14.5
ELECTRICAL DISTRIBUTION SYSTEM	4	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	4 100.0 10.8 7.3	4 7.3
PAVING	5	1 16.7 7.7 1.8	0 0.0 0.0 0.0	0 0.0 0.0 0.0	5 83.3 13.5 9.1	6 10.9

Table 8

Cross-tabulation of Initial Projects, at Rota, Spain (cont'd.)

TYPE	COUNT / ROW PCT / COL PCT / TOT PCT	NO ADP 1	0-25% ADP 2	25-75% ADP 3	100% ADP 5	ROW TOTAL
AIRFIELD	6	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 100.0 2.7 1.8	1 1.8
PIPE WORK	7	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 100.0 5.4 3.6	2 3.6
MECHANICAL DISTRIBUTION SYSTEM	8	3 75.0 23.1 5.5	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 25.0 2.7 1.8	4 7.3
OTHER	9	1 11.1 7.7 1.8	2 22.2 50.0 3.6	0 0.0 0.0 0.0	6 66.7 16.2 10.9	9 16.4
	COLUMN TOTAL	13 23.6	4 7.3	1 1.8	37 67.3	55 100.0

TABLE 9

Cross-tabulation of Initial Projects, at Diego Garcia

TYPE	ADP: COUNT / ROW PCT / COL PCT / TOT PCT	NO ADP 1	25-75% ADP 3	75-99% ADP 4	100% ADP 5	ROW TOTAL
STANDARD BUILDING	1	3 25.0 21.4 6.0	2 16.7 66.7 4.0	0 0.0 0.0 0.0	7 58.3 21.9 14.0	12 24.0
BUILDING W/ MINIMUM FINISH, UTILITIES	2	2 25.0 14.3 4.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	6 75.0 18.8 12.0	8 16.0
BUILDING W/ GREATER FINISH, OR UTILITIES	3	3 30.0 21.4 6.0	0 0.0 0.0 0.0	1 10.0 100.0 2.0	6 60.0 18.8 12.0	10 20.0
ELECTRICAL DISTRIBUTION SYSTEM	4	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 100.0 3.1 2.0	1 2.0

Table 9

Cross-tabulation of Initial Projects at Diego Garcia (cont'd.)

TYPE	COUNT / ROW PCT / COL PCT / TOT PCT	NO ADP 1	25-75% ADP 3	75-99% ADP 4	100% ADP 5	ROW TOTAL
PAVING	5	1 50.0 7.1 2.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 50.0 3.1 2.0	2 4.0
AIRFIELD	6	1 100.0 7.1 2.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 2.0
MECHANICAL DISTRIBUTION SYSTEM	8	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	5 100.0 15.6 10.0	5 10.0
OTHER	9	4 36.4 28.6 8.0	1 9.1 33.3 2.0	0 0.0 0.0 0.0	6 54.5 18.8 12.0	11 22.0
	COLUMN TOTAL	14 28.0	3 6.0	1 2.0	32 64.0	50 100.0

TABLE 10

Cross-tabulation of Final Projects at Puerto Rico

ADP	COUNT / ROW PCT / COL PCT / TOT PCT	STANDARD BLDG. 1	BIDG w/ MINIMUM FINISH 2	BLDG w/ >FINISH, UTILITY 3	PAVING 5	ROW TOTAL
NO ADP	1	5	7	1	2	15
		33.3	46.7	6.7	13.3	51.7
		38.5	77.8	100.0	33.3	
		17.2	24.1	3.4	6.9	
100% ADP	5	8	2	0	4	14
		57.1	14.3	0.0	28.6	48.3
		61.5	22.2	0.0	66.7	
		27.6	6.9	0.0	13.8	
	COLUMN TOTAL	13	9	1	6	29
		44.8	31.0	3.4	20.7	100.0

TABLE 11

Cross-tabulation of Final Projects at Rota, Spain

ADP	COUNT / ROW PCT / COL PCT / TOT PCT	TYPE: STANDARD BLDG. 1	BIDG W/ MINIMUM FINISH 2	BLDG W/ >FINISH, UTILITY 3	PAVING 5	MECH. DISTRIBUTION SYSTEM 8	ROW TOTAL
NO ADP	1	3 27.3 30.0 9.7	1 9.1 16.7 3.2	3 27.3 60.0 9.7	1 9.1 16.7 3.2	3 27.3 75.0 9.7	11 35.5
100% ADP	5	7 35.0 70.0 22.6	5 25.0 83.3 16.1	2 10.0 40.0 6.5	5 25.0 83.3 16.1	1 5.0 25.0 3.2	20 64.5
	COLUMN TOTAL	10 32.3	6 19.4	5 16.1	6 19.4	4 12.9	31 100.0

TABLE 12

Cross-tabulation of Final Projects at Diego Garcia

ADP	COUNT / ROW PCT / COL PCT / TOT PCT	TYPE: STANDARD BLDG. 1	BIDG W/ MINIMUM FINISH 2	BLDG W/ >FINISH UTILITY 3	PAVING 5	MECH. DISTRIBUTION SYSTEM 8	ROW TOTAL
NO ADP	1	2 40.0 25.0 8.3	1 20.0 20.0 4.2	1 20.0 14.3 4.2	1 20.0 100.0 4.2	0 0.0 0.0 0.0	5 20.8
100% ADP	5	6 31.6 75.0 25.0	4 21.1 80.0 16.7	6 31.6 85.7 25.0	0 0.0 0.0 0.0	3 15.8 100.0 12.5	19 79.2
	COLUMN TOTAL	8 33.3	5 20.8	7 29.2	1 4.2	3 12.5	24 100.0

TABLE 13

Breakdown of 84 CPM Values by Type, ADP, Location

VARIABLE	CODE	VALUE LABEL	MEAN	STD DEV	N
FOR ENTIRE POPULATION			29.2895	31.0040	84
TYPE	1	STANDARD BLDG.	20.1500	12.9563	31
ADP	1	NO ADP	24.7750	20.6792	10
LOC	1	PUERTO RICO	32.2920	25.0972	5
LOC	2	ROTA,SPAIN	10.2633	8.2013	3
LOC	3	DIEGO GARCIA	27.7500	16.2069	2
ADP	5	100% ADP	17.9476	6.6012	21
LOC	1	PUERTO RICO	15.2200	4.9511	8
LOC	2	ROTA,SPAIN	16.6700	8.5358	7
LOC	3	DIEGO GARCIA	23.0750		6
TYPE	2	BLDG, MIN. FINISH	23.1900	11.9684	20
ADP	1	NO ADP	21.6444	12.0009	9
LOC	1	PUERTO RICO	18.7400	12.0064	7
LOC	2	ROTA,SPAIN	35.0900	0.0	1
LOC	3	DIEGO GARCIA	28.5300	0.0	1
ADP	5	100% ADP	24.4545	12.3707	11
LOC	1	PUERTO RICO	29.0700	8.7540	2
LOC	2	ROTA,SPAIN	25.2700	11.1488	5
LOC	3	DIEGO GARCIA	21.1275	16.9933	4
TYPE	3	BLDG>FINISH-UTILITY	28.3785	17.8954	13
ADP	1	NO ADP	28.2460	18.3013	5
LOC	1	PUERTO RICO	28.0100	0.0	1
LOC	2	ROTA,SPAIN	18.5800	10.1185	3
LOC	3	DIEGO GARCIA	57.4800	0.0	1
ADP	5	100% ADP	28.4612	18.9098	8
LOC	2	ROTA,SPAIN	15.6700	2.0223	2
LOC	3	DIEGO GARCIA	32.7250	20.3110	6

Table 13

Breakdown of 84 CPM Values By TYPE, ADP, LOCATION (cont'd.)

VARIABLE	CODE	VALUE LABEL	MEAN	STD DEV	N
TYPE	5	PAVING	61.7869	63.4212	13
ADP	1	NO ADP	33.9075	16.7517	4
LOC	1	PUERTO RICC	33.2400	16.1362	2
LOC	2	ROTA,SPAIN	17.5500	0.0	1
LOC	3	DIEGO GARCIA	51.6000	0.0	1
ADP	5	100% ADP	74.1778	73.2584	9
LOC	1	PUERTO RICC	45.9550	33.9265	4
LCC	2	ROTA,SPAIN	96.7560	91.8509	5
TYPE	8	MECH.DIST.SYS.	28.5314	21.7514	7
ADP	1	NO ADP	40.4500	31.2807	3
LOC	2	ROTA,SPAIN	40.4500	31.2807	3
ADP	5	100% ADP	19.5925	6.7332	4
LOC	2	ROTA,SPAIN	15.5100	0.0	1
LCC	3	DIEGO GARCIA	20.9533	7.5427	3

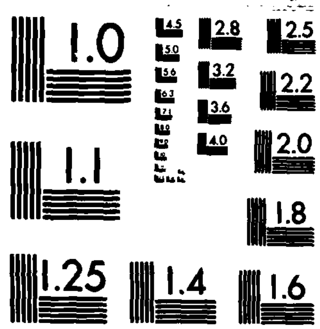
AD-A155 643 MINICOMPUTERS AND NAVAL MOBILE CONSTRUCTION BATTALION PRODUCTIVITY(U) NAVAL POSTGRADUATE SCHOOL MONTEREY CA G R WEGENER DEC 84 2/2

UNCLASSIFIED F/G 9/2 NL

END

FILMED

DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

APPENDIX C

PERCENT DIRECT LABOR DATA

TABLE 14

Case Identification for Percent Direct Labor

BTNCODE	Mainbody Site	Battalion	From	To
215	Rota, Spain	5	Nov 76	Jul 77
223		133	Jul 77	Mar 78
236		40	Mar 78	Nov 78
241		1	Nov 78	Jul 79
252		62	Jul 79	Mar 80
267		74	Mar 80	Nov 80
274		4	Nov 80	Jul 81
285		5	Jul 81	Mar 82
513	Diego Garcia	133	Jun 76	Feb 77
522		62	Mar 77	Nov 77
537		74	Nov 77	Jul 78
544		4	Jul 78	Mar 79
555		5	Mar 79	Nov 79
563		133	Nov 79	Jul 80
576		40	Jul 80	Mar 81
581		1	Mar 81	Nov 81
592		62	Oct 81	Jul 82
111	Puerto Rico	1	Jul 76	Apr 77
124		4	Apr 77	Jan 78
135		5	Jan 78	Sep 78
143		133	Sep 78	May 79
156		40	May 79	Jan 80
161		1	Jan 80	Sep 80
172		62	Sep 80	May 81
187		74	May 81	Jan 82
416	Guam	40	Jan 77	Oct 77
421		1	Oct 77	May 78
432		62	May 78	Jan 79
447		74	Jan 79	Sep 79
454		4	Sep 79	May 80
465		5	May 80	Jan 81
473		133	Jan 81	Sep 81
486		40	Sep 81	Apr 82
317	Okinawa, Japan	74	Sep 76	Apr 77
328		3	Apr 77	Oct 77
339		3	Jul 77	Mar 78
348		3	Mar 78	Nov 78
359		3	Oct 78	Jun 79
368		3	Jun 79	Jan 80
379		3	Jan 80	Aug 80
388		3	Aug 80	Mar 81
399		3	Mar 81	Nov 81

TABLE 15

Percent Direct Labor Data

CASE	BTNCODE	DLPERS	MBEM	%LOSTDAY	MBACTDL
1	215	na	415	na	na
2	223.	34.1	450.	3.5	17.6
3	236.	32.4	370.	3.1	20.7
4	241	na	na	na	na
5	252.	na	338.	na	20.8
6	267.	32.0	431.	0.0	19.0
7	274.	25.9	361.	0.0	20.4
8	285.	na	403.	3.5	23.0
9	513.	na	595.	na	22.0
10	522.	38.0	634.	4.3	23.0
11	537	44.0	644.	na	na
12	544.	34.0	645.	0.0	31.0
13	555.	36.0	555.	0.0	27.0
14	563	na	na.	na	na
15	576.	43.0	597.	0.6	31.0
16	581.	na 0	659.	na	36.0
17	592.	48.0	736.	2.3	37.0
18	111.	na	527.	na	26.0
19	124.	45.0	455.	5.8	22.2
20	135.	31.0	489.	1.0	23.1
21	143.	na	425.	0.0	24.0
22	156.	17.0	293.	3.2	15.0
23	161.	na.0	365.	0.0	26.5
24	172.	na.0	450.	0.0	24.8
25	187.	33.0	537.	na	18.7
26	416.	38.0	504.	na	32.0
27	421.	na	493.	2.3	27.0
28	432.	37.8	448.	na	32.3
29	447.	32.0	365.	na	16.0
30	454.	23.0	328.	1.1	18.1
31	465.	31.0	380.	11.0	17.0
32	473.	na.0	504.	na	17.4
33	486.	30.0	521.	3.2	15.1
34	317.	na	432.	na	19.3
35	328.	na	190.	na	18.0
36	339.	34.0	185.	0.0	16.0
37	348.	35.0	174.	1.2	19.0
38	359.	21.0	157.	1.7	21.0
39	368.	38.0	166.	2.6	17.0
40	379.	34.0	147.	0.0	23.0
41	388.	na	180.	0.6	21.0
42	399.	na	177.	0.0	22.0

Table 15

Percent Direct Labor Data (cont'd.)

CASE	COTIBTN	WTAVETOF	COMPUTER	MO%INT	CONDUCT
1	13.5	na	0.	na	na
2	18.0	na	0.	0.0957	1.4333
3	8.0	1.4207	0.	0.0853	3.5500
4	9.0	na	0.	na	na
5	16.0	na	1.	0.0788	5.9905
6	13.0	1.1959	1.	0.1362	1.5056
7	12.0	1.1668	1.	0.0800	3.1218
8	4.0	1.6591	1.	0.0655	2.0522
9	5.0	1.0332	0.	0.2161	na
10	13.5	1.5026	0.	0.4419	2.7079
11	16.0	0.9399	0.	na	6.7317
12	8.0	1.3637	1.	0.2530	2.2183
13	13.0	1.5865	1.	0.1451	na
14	6.0	na	1.	na	na
15	7.0	1.4922	1.	0.2952	2.3034
16	14.0	1.2984	1.	0.3179	na
17	20.0	1.1513	1.	0.2313	3.4091
18	4.0	na	0.	0.3817	na
19	14.5	1.1347	0.	na	na
20	12.0	1.1503	0.	0.1173	0.5714
21	7.0	1.4280	0.	0.0740	1.8000
22	16.0	1.4663	1.	0.1254	2.2540
23	11.5	1.1368	1.	na	na
24	6.0	na	1.	na	na
25	14.0	1.5751	1.	0.1105	3.0000
26	11.5	1.8611	0.	0.1462	9.3860
27	17.0	1.1119	0.	0.1766	2.8235
28	8.5	1.2570	0.	0.1744	4.3626
29	12.0	1.2891	0.	0.1821	4.0132
30	16.0	1.0311	1.	0.1170	na
31	14.0	0.9855	1.	0.1165	3.2549
32	14.5	na	1.	0.0888	na
33	20.5	1.0197	1.	0.1824	1.9832
34	7.0	na	0.	na	6.2097
35	6.1	na	0.	0.1364	na
36	6.5	1.2031	0.	0.0923	2.2982
37	14.0	0.3409	0.	0.1269	2.1579
38	21.0	0.2995	0.	0.1105	1.6154
39	6.2	0.3772	0.	0.0729	0.4767
40	9.5	0.3948	1.	0.1122	1.0175
41	16.5	0.2974	1.	0.1137	1.0855
42	24.0	0.3907	1.	na	1.6780

United States Naval Mobile Construction Battalion
Manpower Authorization (Non-Mobilization)

	Occupational Field 13							Non-Occupational Field 13						
	eo	cm	bu	sw	ut	ce	ea	sk	yn	pn	hm	ms	other	total
e9	1	0	1	0	1	0	0	0	0	0	0	0	0	3
e8	1	1	1	1	1	1	0	1	0	0	0	0	0	7
e7	3	3	8	3	1	2	1	0	1	1	1	1	2	27
e6	15	7	19	7	6	6	1	2	1	1	1	4	8	78
e5	18	15	39	7	11	12	4	4	2	2	4	5	7	130
e4	28	17	46	13	14	15	4	6	3	2	2	7	10	167
e1-3	26	14	43	15	13	14	4	3	4	2	0	3	9	150
total	92	57	157	46	47	50	14	16	11	8	8	20	35	562

Figure C.1 NMCB Peacetime Manning Allowance.

LIST OF REFERENCES

1. Civil Engineering Support Office, Automated Data System Development Plan for NMCB/MIS, Port Hueneme, CA, February 1984

2. "Computer Vanguard", Engineering News Record, pp. 11-12, 1 July 1982.

3. OPNAVINST 5450.46G, United States Naval Mobile Construction Battalions; Doctrine and Policy Governing, 4 December 1975.

4. OPNAV 1000/2, Manpower Authorization, 15 May 1982

5. "Construction Scoreboard", Engineering News Record, 8 April 1976.

6. "The ENR 400", Engineering News Record, 15 April 1976.

7. Kellogg, J. C., Howell, G. E., and Taylor, D. C., "Hierarchy Model of Construction Productivity", Journal of the Construction Division, American Society of Civil Engineers, pp. 137, March 1981.

8. Choromokos, J. Jr. and McLee, K. E., "Construction Productivity Improvement Survey", Construction Productivity Frontiers, pp. 1, IIT Center, Chicago, Illinois, January 1980.

9. Rees, A., "Improving Concepts and Techniques for Productivity Measurements", Monthly Labor Review, pp. 23-27, September 1979.

10. Kendrick, J. W., Understanding Productivity, John Hopkins University Press, 1971.

11. Measurement and Interpretation of Productivity, National Research Council, National Academy of Sciences, 1979.

12. Nelson, R. R., "Research on Productivity Growth and Productivity Differences: Dead Ends and New Departures", Journal of Economic Literature, v. XIX, September 1981.

13. Bortz, S. A., Editorial, Construction Productivity Frontiers, pp. i, IIT Center, Chicago, Illinois, October 1980.

14. Dossantos, W. A., _NCF Readiness Training, Peacetime Construction and the War Mission: A Question of Congruency_, M. S. Thesis, Naval Postgraduate School, Monterey, California, September 1983.

15. "Construction Scoreboard", _Engineering News Record_, pp. 24, 9 January 1975.

16. "Construction Scoreboard", _Engineering News Record_, pp. 30, 8 January 1976.

17. "Construction Scoreboard", _Engineering News Record_, pp. 22, 6 January 1977.

18. "Construction Scoreboard", _Engineering News Record_, pp. 25, 12 January 1978.

19. "Construction Scoreboard", _Engineering News Record_, pp. 31, 4 January 1979.

20. "ENR Market Trends", _Engineering News Record_, pp. 36, 10 January 1980.

21. "ENR Market Trends", _Engineering News Record_, pp. 44, 8 January 1981.

22. "ENR Market Trends", _Engineering News Record_, pp. 44, 7 January 1982.

23. Wonnacott, T. H., and Wonnacott, R. J., _Introductory Statistics_, 3rd ed., pp. 241-254, Wiley, 1977.

24. Turban, E., and Meredith, J. R., _Fundamentals of Management Science_, rev. ed., pp. 36, Business Publications, Inc., 1981.

25. COMCBLANTINST 5312.1, _United States Atlantic Fleet Naval Construction Force Timekeeping: procedures for_, 18 June 1979.

26. Anthony, R. N., and Herzlinger, R. E., _Management Control in Nonprofit Organizations_, pp. 250, Irwin, 1980.

27. COMCBPAC/LANTINST 3121.1, _Deployment Completion Reports for Pacific and Atlantic Naval Mobile Construction Battalions: procedures for submittal of_, 21 September 1977.

28. NavPers 15909C, _Enlisted Transfer Manual_, U. S. Naval Military Personnel Command, Washington, D.C.

INITIAL DISTRIBUTION LIST

	No. Copies
1. Defense Technical Information Center Cameron Station Alexandria, Virginia 22314	2
2. Library, Code 0142 Naval Postgraduate School Monterey, California 93943	2
3. Civil Engineer Corps Officers School Port Hueneme, California 93043	1
4. Civil Engineer Support Office Naval Construction Battalion Center Port Hueneme, California 93043	1
5. Commander Naval Facilities Engineering Command 200 Stovall Street Alexandria, Virginia 22332	1
6. Commander Naval Construction Battalions U. S. Pacific Fleet Makalapa Hi Pearl Harbor, Hawaii 96860	1
7. Commander Naval Construction Battalions U. S. Atlantic Fleet Naval Amphibious Base Little Creek Norfolk, Virginia 23521	1
8. Commanding Officer Navy Public Works Center (LCDR G.R. Wegener) PO Box 24003 Oakland, California 94623	3
9. Prof. D. Boger, Code 54DB Department of Administrative Science Naval Postgraduate School Monterey, California 93943	1
10. Prof. K. Euske, Code 54KE Department of Administrative Science Naval Postgraduate School Monterey, California 93943	1

END

FILMED

7-85

DTIC